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EDN®

Part 4 of EDN's Decade 90 Series

Dynamic testing of ADCs

Tools for IEEE-488 program generation

Electro/88 preview

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS

Single-IC modems perform as full-size boards

ANALOG DEVICES

3µs, 12-Bit Monolithic ADC

AD7672

FEATURES
- 12-Bit Resolution and Accuracy
- Fast Conversion Time
  - AD7672XX03 – 3µs
  - AD7672XX05 – 5µs
  - AD7672XX10 – 10µs
- Unipolar or Bipolar Input Ranges
- Low Power: 110mW
- Fast Bus Access Times: 90ns
- Small, 0.3", 24-Pin Package

AD7672 Functional Block Diagram

PRODUCT DESCRIPTION

The AD7672 is a high-speed 12-bit ADC, fabricated in an advanced, mixed technology, Linear-Compatible CMOS (LC^2MOS) process, wh ch combines precision bipolar components with low-power, high-speed CMOS logic. The AD7672 uses an accurate high-speed DAC and comparator in an otherwise conventional successive-approximation loop to achieve conversion times as low as 3µs while dissipating only 110mW of power.

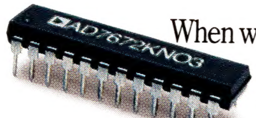
To allow maximum flexibility, the AD7672 is designed for use with an external reference voltage. This allows the user to choose a reference whose performance suits the application, or to drive many AD7672s from a single system reference, since the reference input of the AD7672 is buffered and draws little current. For digital signal processing applications, where absolute accuracy and temperature coefficients may be unimportant a low-cost reference can be used. For maximum precision, the AD7672 can be used with a high-accuracy reference such as the AD588.

The on-chip clock-circuit may be used with a crystal for accurate definition of conversion time Alternatively the clock input may be driven from an external source such as a microprocessor clock.

PRODUCT HIGHLIGHTS

1. Fast, 3µs, 5µs and 10µs conversion speeds make the AD7672 ideal for a wide range of applications in telecommunications, sonar and radar signal processing or any high-speed data acquisition system.
2. LC^2MOS circuitry gives high precision with low power drain (110mW typ)
3. Choice of 0 to +5V, 0 to +10V or ±5V input ranges, accomplished by pin-strapping.
4. Fast, simple, digital interface has a bus access time of 90ns allowing easy connection to most microprocessors.
5. Available in space-saving 24-pin, 0.3" DIP or surface mount package.

AT 5µS, WE SET THE 12-BIT A/D RECORD. THIS PAGE TELLS HOW WE BROKE IT.



When we introduced our AD7572, it set the monolithic 12-bit A/D conversion speed record at 5µs. Now, our AD7672 establishes a new record with an even faster conversion time of only 3µs.

The AD7672 reaches this blazing speed with only 110mW of power dissipation because, like the AD7572, it's manufactured on an advanced merged bipolar/CMOS process.

The 90ns bus access time of the AD7672 affords easy interfacing with most microprocessors, while the +5V and –12V nominal power supply voltages allow its use in PC and modem designs. All this is available in a narrow 0.3" DIP or a surface mount package, so whatever your application, the AD7672 won't take up much space.

The AD7672 also features unipolar or bipolar analog inputs that are selected by pin-strapping. This lets you avoid external circuitry for input range changing.

For more information on how the AD7672 can speed up your designs, contact the Analog Devices office nearest you.

ANALOG DEVICES

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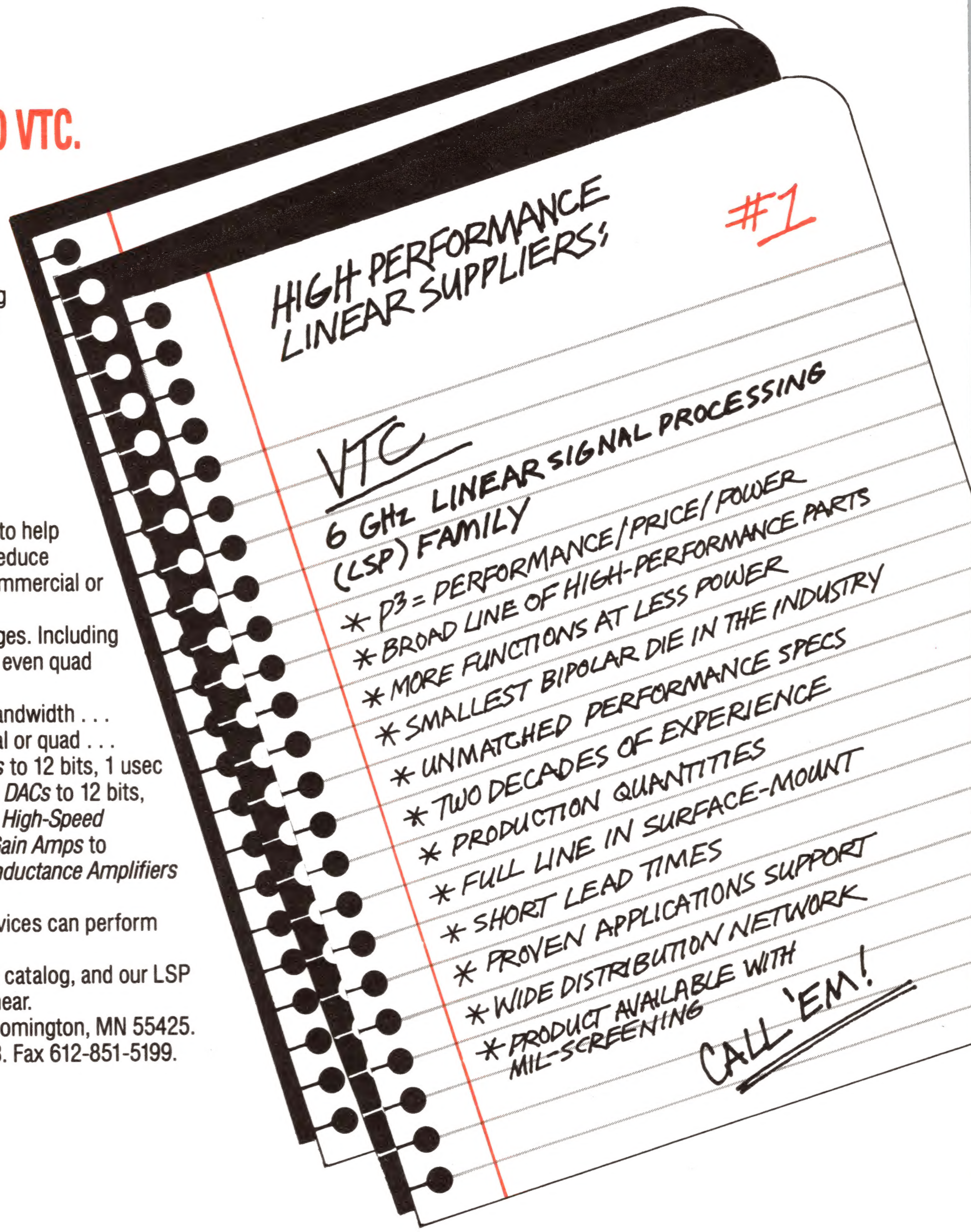

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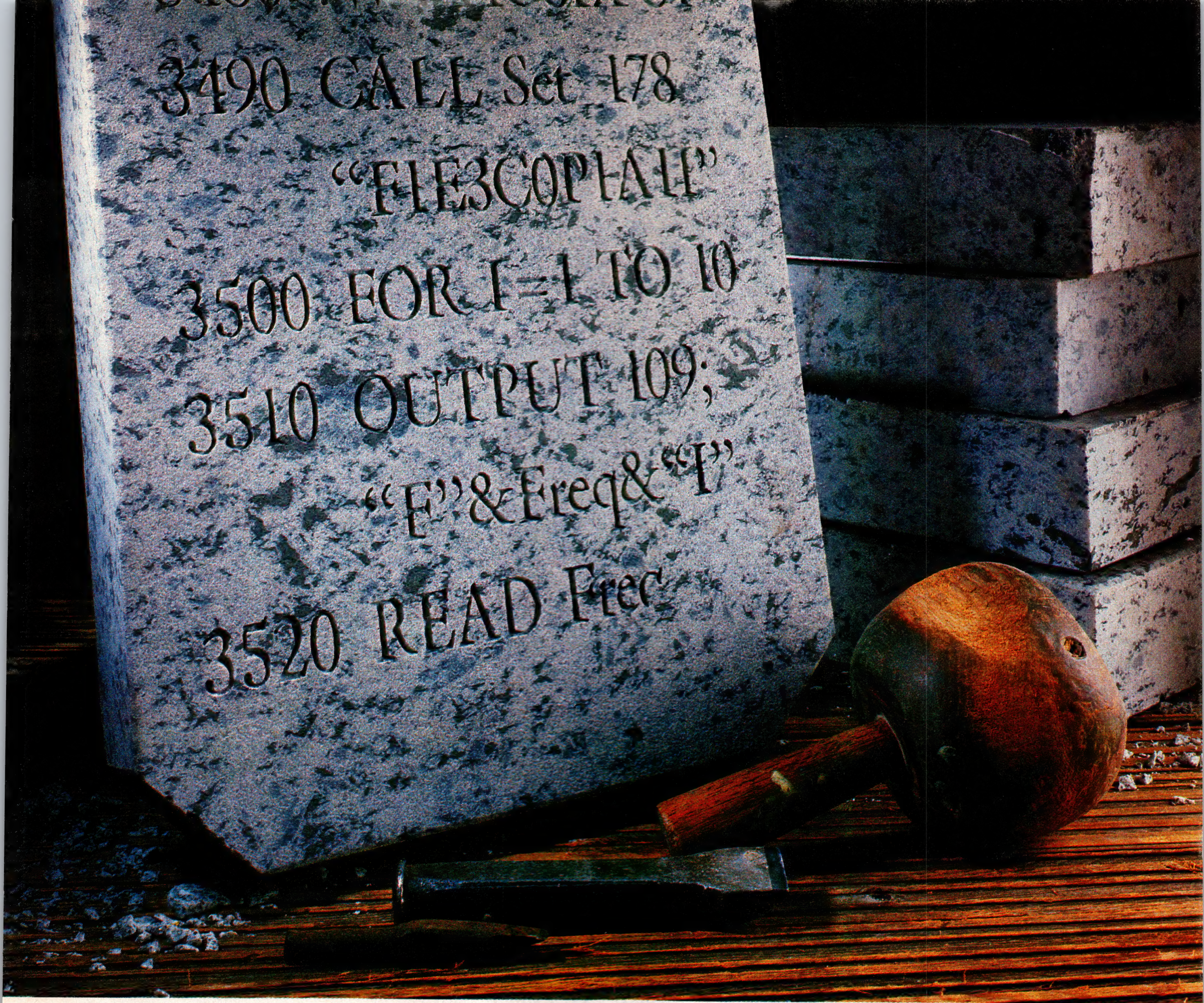

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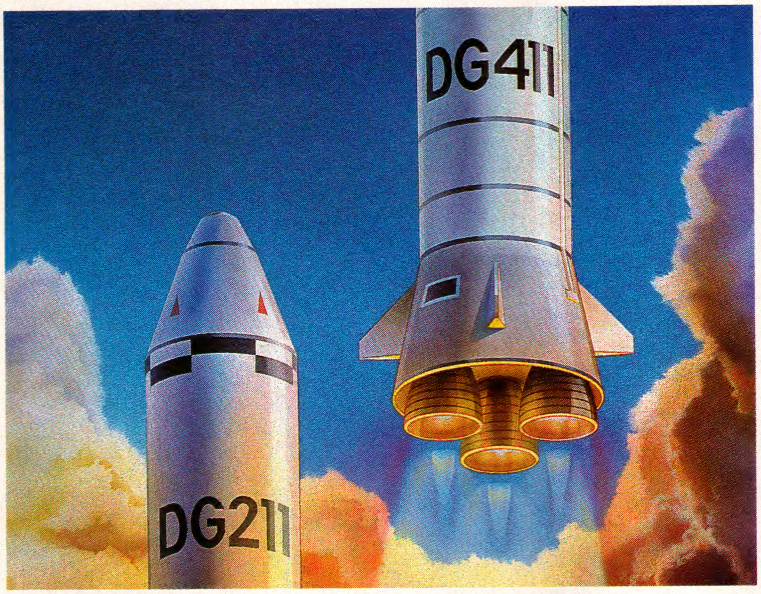

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Quad Analog Switch Performance Comparison

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175 Ω	On Resistance	35 Ω
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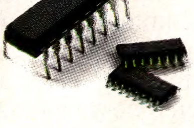

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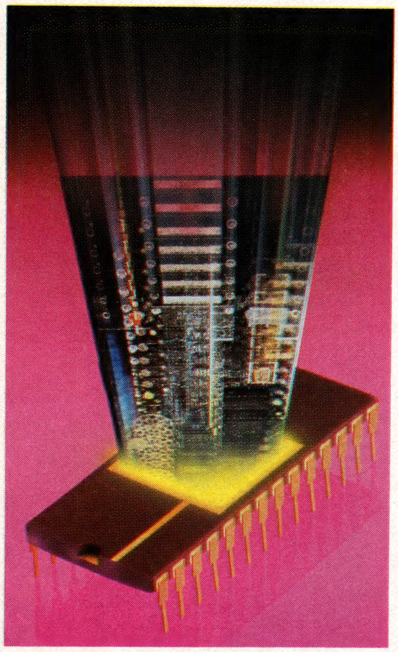
Volume 33, Number 8

EDN

April 14, 1988

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS



On the cover: *Single-IC modems are eliminating board-level modems that transmit at 1200 bps or less. And by adding a single-IC modem to your embedded application, you can have a virtual front-end processor for communicating over the public switched-telephone network or via a communication satellite link. See pg 118. (Photo courtesy Silicon Systems Inc)*

SPECIAL ISSUE: COMMUNICATIONS TECHNOLOGY

DESIGN FEATURES

Continued on page 7

EDN®(ISSN 0012-7515) is published 38 times a year (biweekly with 1 additional issue a month) by Cahners Publishing Company, A Division of Reed Publishing USA, 275 Washington Street, Newton, MA 02158-1630. Terrence M McDermott, President; Frank Sibley, Electronics/Computer Group Vice President; Jerry D Neth, Vice President/Publishing Operations; J J Walsh, Financial Vice President/Magazine Division; Thomas J Dellamaria, Vice President/Production and Manufacturing. Circulation records are maintained at Cahners Publishing Company, 44 Cook Street, Denver, CO 80206-5191. Telephone: (303) 388-4511. Second-class postage paid at Denver, CO 80206-5191 and additional mailing offices. POSTMASTER: Send address corrections to EDN®at the Denver address. Saul Goldweitz, Chairman; Ronald G Segel, President and Chief Executive Officer; Robert L Krakoff, Executive Vice President; William M Platt, Senior Vice President. Annual subscription rates for nonqualified people: USA, $100/year; Canada/Mexico, $115/year; Europe air mail, $135/year; all other nations, $135/year for surface mail and $210/year for air mail. Except for special issues where price changes are indicated, single copies of regular issues are available for $6, $8, and $10 (USA, Canada/Mexico, and foreign). Please address all subscription mail to Eric Schmierer, 44 Cook Street, Denver, CO 80206-5191.

BPA ABP

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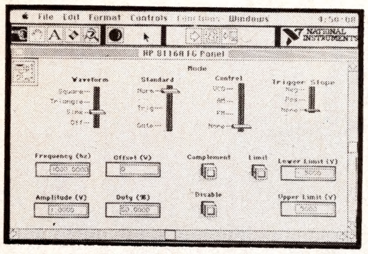

***You can now obtain PC-based CASE tools** that speed up the process of developing software for IEEE-488 systems (pg 71).*

Continued on page 9

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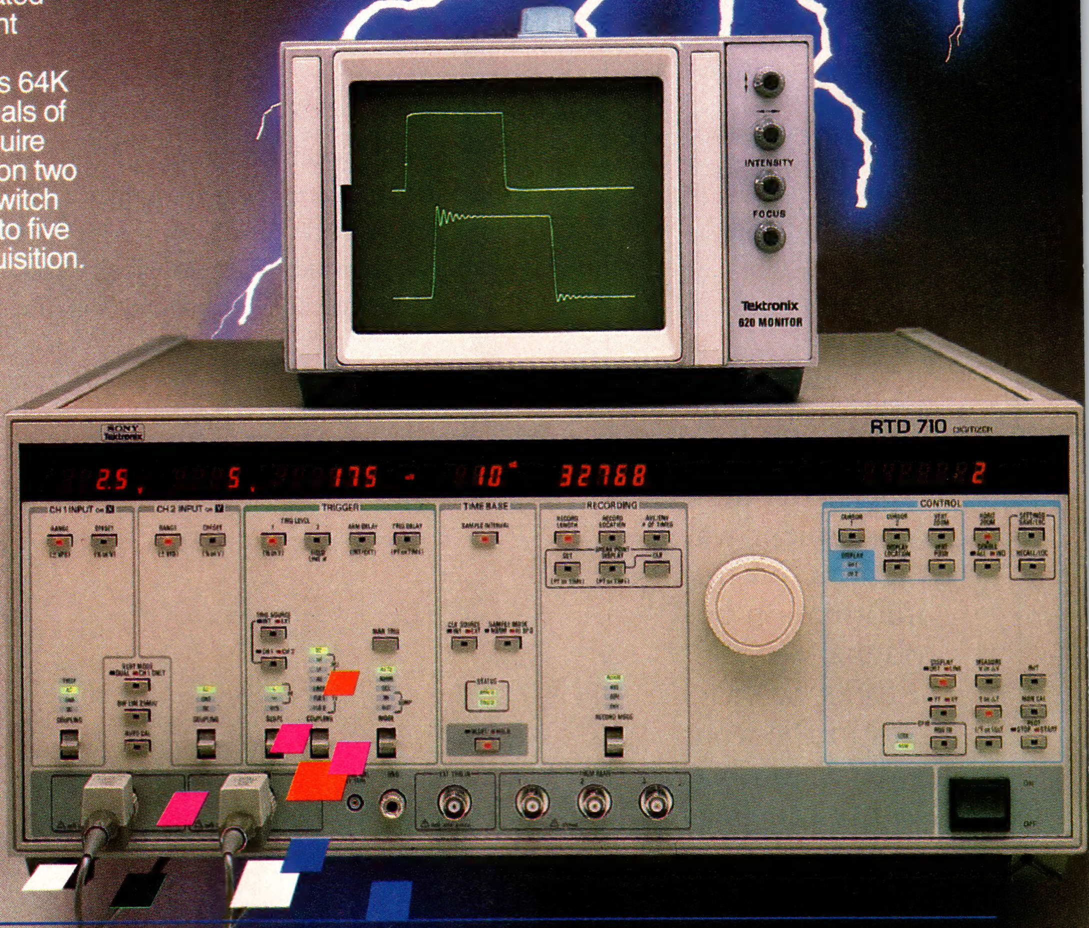

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CIRCLE NO 7

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EDN

April 14, 1988

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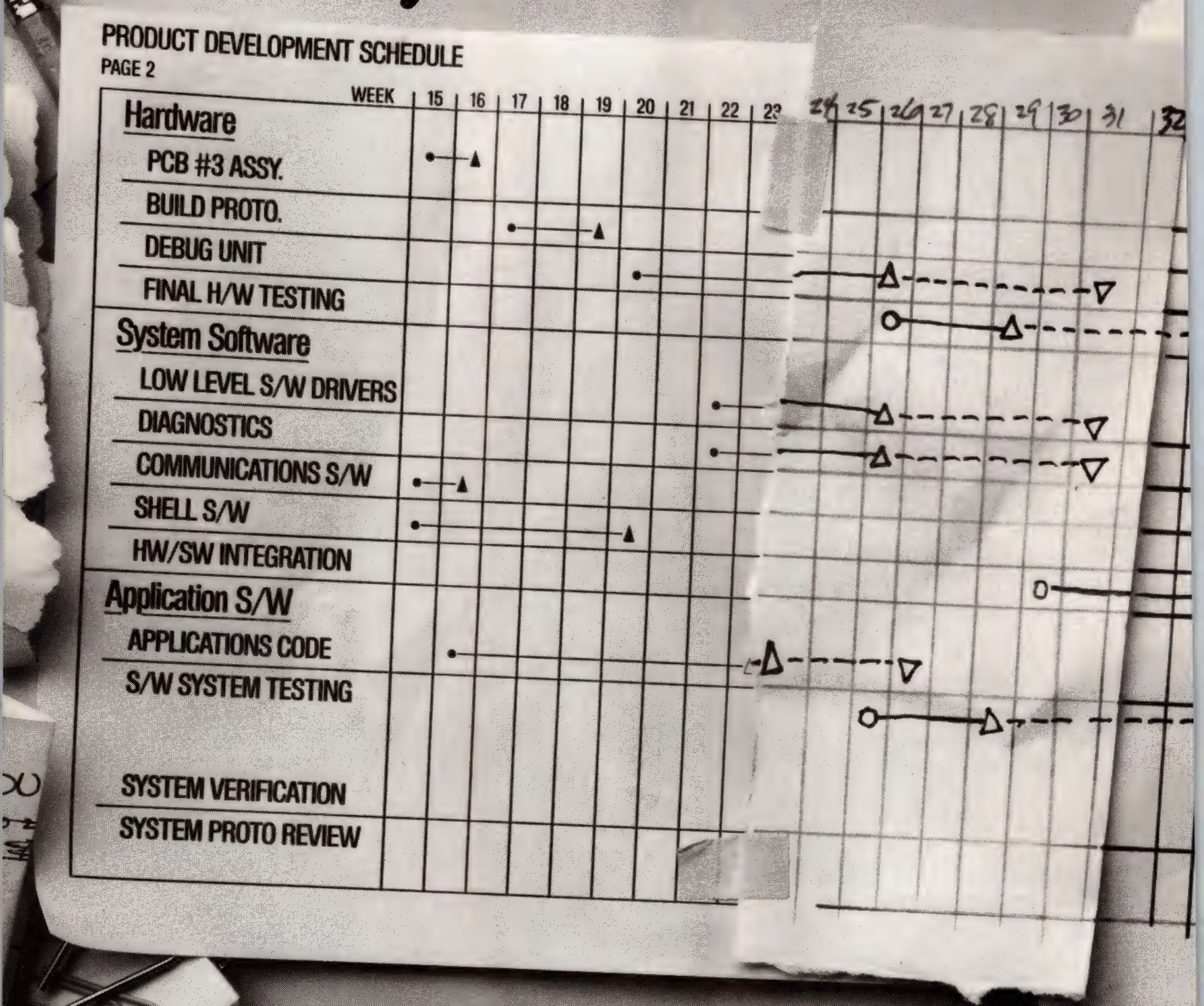

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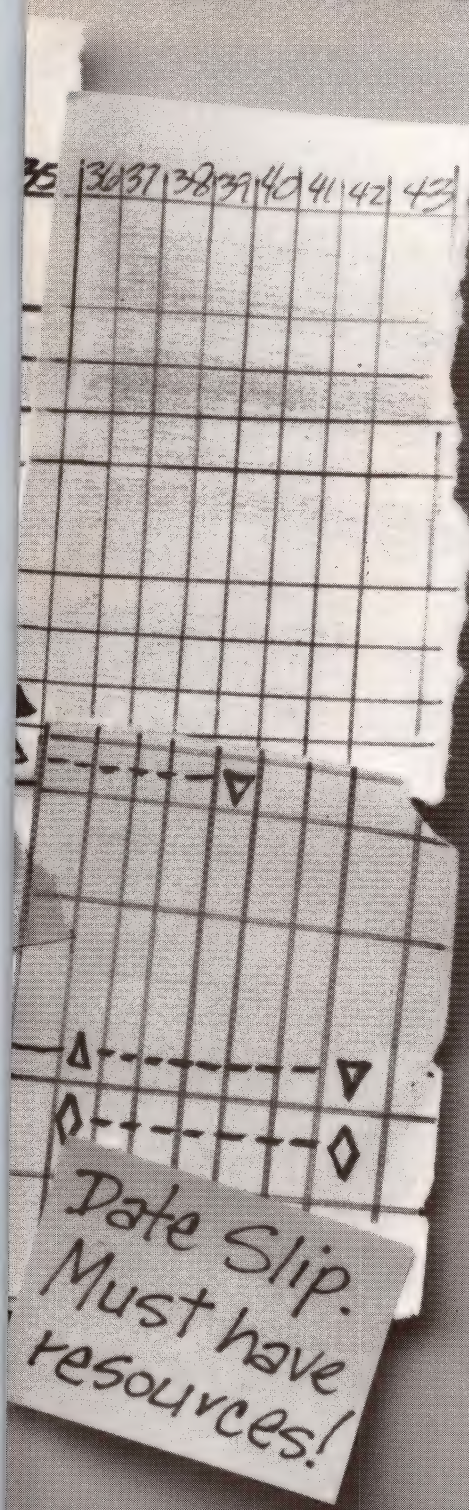

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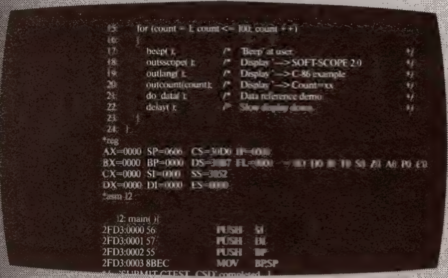

pled with our ES 1800 emulator. You can use commands to examine variables on the fly, check contents of registers, and determine current position in code. And real-time trace is displayed as source level statements, machine instructions or bus cycles.

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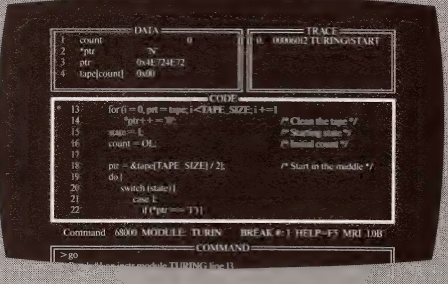

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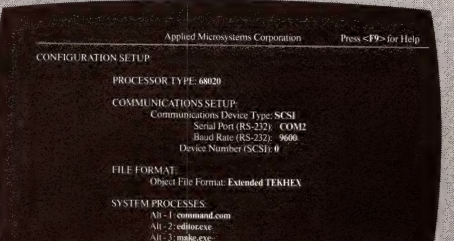

Also included are a logic state analyzer probe; the SCSI option for increasing download speeds by up to 30 times; plus up to 2 Megabytes of overlay memory.

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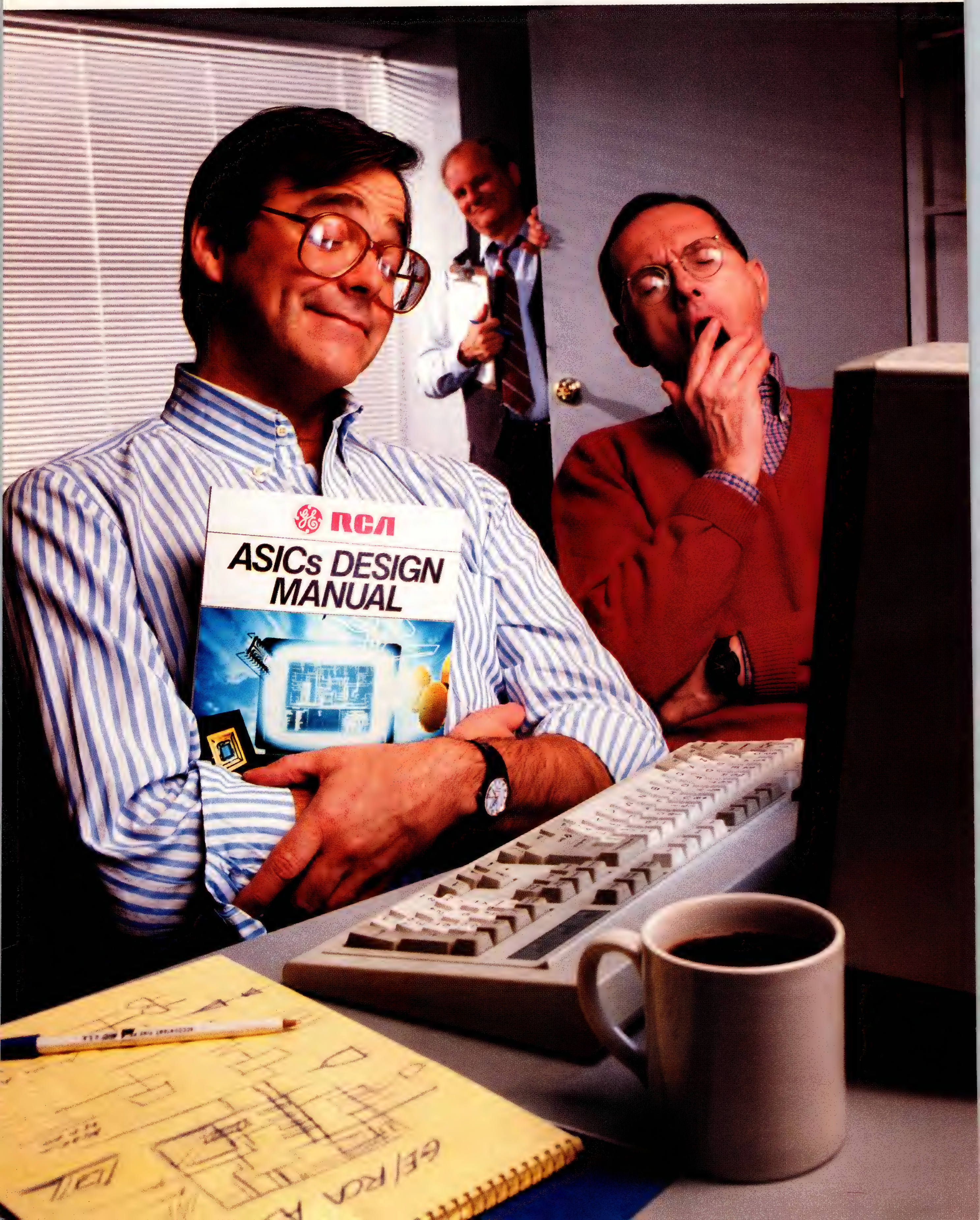

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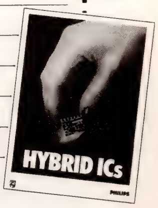
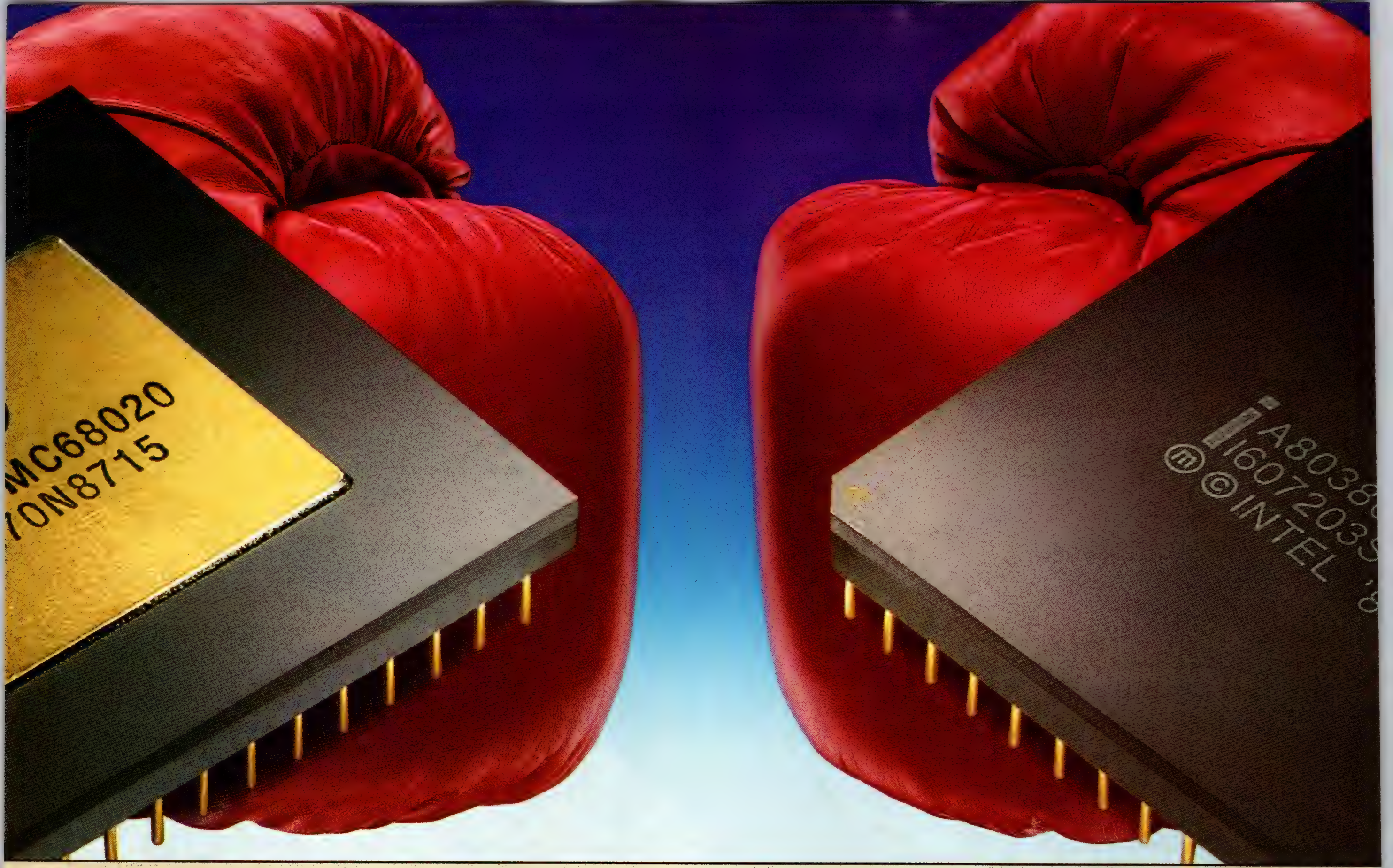


For custom hybrid ICs
The name is Philips

PHILIPS

CIRCLE NO 18



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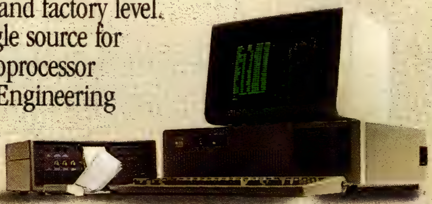

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Circle No. 13 for demonstration

Circle No. 12 for literature

NEWS BREAKS

EDITED BY JOANNE CLAY

MODULAR LOGIC ANALYZER GROWS WITH YOUR NEEDS

The ML4400 Logic Analyzer from Arium Corp (Anaheim, CA, (714) 978-9531) is based on a mainframe that can accept as many as four capture modules. At present, you can choose from a high-speed module and a standard module. The high-speed module acquires four channels at 400 MHz (32,768 samples), eight at 200 MHz (16,384 samples), or 16 at 100 MHz (8192 samples). The standard module acquires 20 channels asynchronously at 100 MHz (8192 samples) or 40 channels synchronously at 50 MHz (4096 samples). With an expansion pod, you can acquire 80 channels at 25 MHz (2048 samples). You can also use any combination of the modules, so you can configure the system to acquire 80 channels synchronously at 50 MHz and eight channels asynchronously at 400 MHz. Or, with four of the standard modules, you could trace program flow from four separate 68020 pods or have a 160-channel, 50-MHz synchronous logic analyzer. The ML4400 mainframe costs $2895 and comes with a 7-in. CRT, parallel and serial printer outputs, a CGA/EGA-compatible color video interface, an IBM-PC-style keyboard interface, trigger outputs, eight nonvolatile setups, and a ROM emulator (minus the probe). A number of options are available: a 3.5-in. floppy-disk drive costs $795, a high-speed module is $1995, a standard module is $1795, and a 200- or a 400-MHz probe sells for $1995. You can purchase a starter system that includes the mainframe, a standard module, and a 40-channel logic pod for $4995. Many popular μP pods are also available.—David Shear

SOFTWARE LIBRARIES IMPLEMENT SIGNAL-PROCESSING FUNCTIONS

The 387FFT from MicroWay (Kingston, MA, (617) 746-7341) is a library of assembly-language signal-processing functions—such as FFT, convolution, correlation, and autocorrelation—for use on the IBM PC, PC/XT, PC/AT, and compatible computers with numeric coprocessors. The library supports most popular MS-DOS, C, Fortran, and Basic compilers. Although the 640k-byte MS-DOS memory limits you to a maximum 2-dimensional FFT size of 256×256, you can use the library's DISKFFT utility to perform 2-D transforms on data files as large as 32M bytes that can hold as many as 2048×2048 complex points (an array size common in image-processing applications). For RAM-based 2-D transforms on arrays requiring as many as 16G bytes, the vendor supplies the 387FFT-PM library. The 387FFT-PM runs only in protected mode and requires the vendor's protected-mode C or Fortran compiler. Each library is $249.

—Margery S Conner

CAE SOFTWARE FOR THE IBM PC BREAKS THE 640k-BYTE BARRIER

IBM PCs and compatible computers impose a severe handicap on most application software: a 640k-byte memory ceiling. The Workview 2000 and 3000 CAE software packages from Viewlogic Systems (Marlboro, MA, (617) 480-0881) break this barrier and, according to the vendor, deliver workstation-like performance on a PC. Both packages incorporate the schematic-capture, analog- and digital-simulation, and XNS network-communications capabilities of the company's earlier products. To these features, the new packages add support for high-resolution graphics (1024×768 pixels) for selected graphics boards, VHDL behavioral-level simulation, EDIF 2 0 0 data-file capability, the TCP/IP network protocol, a preplacement editor, and a schematic librarian. Though both software products operate with DOS, Workview 2000 (for 80286-based PCs) can use as much as 16M bytes of memory, and Workview 3000 (for 80386-based machines), can use as much as 4G bytes of RAM, if you can find a way to cram that much memory into your computer. The packages, which will begin shipping in June, will cost $10,000 to $14,000.—Steven H Leibson

SYSTEMS MAKE μPROGRAM DEVELOPMENT EASIER AND LESS COSTLY

If the development systems just introduced by Step Engineering (Sunnyvale, CA, (408) 733-7837) and Hilevel Technology (Irvine, CA, (714) 727-2100) are any indication, the industry is about to witness a resurgence of interest in microprogrammed computating architectures. Step aims its entry, the Step 50, at the middle of the market: A PC-hosted, 96-bit-wide, 25-MHz unit with probes and a built-in logic analyzer costs $16,800. The Step 50's capabilities far exceed those of the company's Microstep, which sells for $6500. Step's top-of-the-line product, the Step 40, targets the integration of multiple microprogrammed processors and starts at $25,000. Hilevel's 50-MHz DS5000 includes a 256-channel logic analyzer and a 512-bit-wide emulation memory. It sports innovations that make it easier to use than its predecessors; at $10,000 to $20,000, it's also less expensive, but its specs are better. The DS5000's probes contain CMOS static RAMs, and 7-ft ribbon cables link the probes to the mainframe. Because signals don't have to travel over cables to get to and from memory, the probes can contain relatively low-cost, medium-speed RAMs.—Dan Strassberg

GATE-ARRAY SOFTWARE DELIVERS OVER 80% UTILIZATION

Silvar-Lisco (Menlo Park, CA, (415) 324-0700) has announced its vendor-independent layout software for the design of very large gate arrays. Called Avant Gards, the software can be used to design arrays that use more than 150,000 gates. The software supports a variety of technologies, including CMOS, BiCMOS, and GaAs. You can use the sea-of-gates, row, column, and island gate-array styles. Floor-planning, partitioning, placement, and routing are all automatic and ensure that every net meets user-defined timing constraints. The vendor claims that gate utilization for designs employing sea-of-gates construction and three metal layers has been proven at 80 to 90%. The software is fully integrated with the existing CAD tools from Silvar-Lisco and runs on a variety of workstations. The software will be available by mid-April. The Avant Gards product family starts at $60,000, depending on host and configuration.—Richard A Quinnell

INTERFACE CHIP FAMILY SUPPORTS PROPOSED SCSI-2 STANDARD

Marketing and technology partners NCR Microelectronics Div (Dayton, OH, (800) 334-5454) and Emulex Corp (Costa Mesa, CA, (714) 662-5600) have added four devices to their 53C90 family of SCSI (Small Computer Systems Interface) ICs. All of the new ICs support the proposed SCSI-2 standard; they have such features as bus-initiated selection for extended message selections, select with ATN3 command, and 10-byte Group 2 commands. The chips also include state machines that perform common SCSI-2 bus sequences along with the SCSI sequences supported by the 53C90. The 53C90A adds the SCSI-2 features, yet is pin compatible with the 53C90. The 53C90B adds a parity check to operations between the SCSI bus and memory.

Like the 53C90, the new chips operate with 8-bit maximum asynchronous and synchronous transfer rates of 3M bytes/sec and 5M bytes/sec, respectively. The 53C94 and 53C95 also include a split-bus feature that supports wider SCSI data paths, allowing faster transfers. Both devices support a 16-bit SCSI data path, and both can perform either 8- or 16-bit DMA transfers to memory. The 53C94 handles only single-ended SCSI operations, but the 53C95 includes logic that can control differential transceivers. The software for all members of the 53C90 family is compatible. The 53C90A/B costs $20.44 (1000); samples will be available in July. Samples of the 53C94/95 will be available in June; the part will cost $25.55 (1000).—Maury Wright

NEWS BREAKS: INTERNATIONAL

ICs PROVIDE A BUILDING-BLOCK APPROACH TO MICROWAVE DESIGN

In the next few months, the Microwave Common Module Group—which comprises Ferranti Computer Systems Ltd (Manchester, UK, TLX 76166), M/A-Com Ltd (Dunstable, UK, TLX 82295), Marconi Electronic Devices Ltd (Lincoln, UK, TLX 56380), and Plessey Microwave Ltd (Towcester, UK, TLX 311441)—will release a 6- to 18-GHz, low-noise, single-stage broadband amplifier. This component represents the first of a series of microwave ICs that let you adopt a building-block approach when designing microstrip subsystems. All these ICs (referred to as microwave common modules) will be built to a common standard that includes interface, performance-level, and physical-dimension requirements. The broadband amplifier, which is expected to sell for around £100 (500), specs 5.5-dB gain, ±0.5-dB gain ripple, 5-dB noise, and 10-dBm output power. It requires a single 8V supply. The companies are also developing microwave modules that include a 6- to 18-GHz oscillator, a mixer, a switch, and a low-noise amplifier.—Peter Harold

CO_2 LASER CUTS THE COST OF LASER-SOLDERING EQUIPMENT

By using an infrared CO_2 laser, a consortium of British companies has developed an automatic laser-soldering system that's powered from a normal single-phase ac line supply. To evaluate the system for the soldering of surface-mount and hybrid assemblies, the firms have produced a single-operator soldering workstation that's about the size of an office desk. It requires no special cooling, air, or vacuum supplies. The workstation's laser has a maximum output power of 30W and can generate a minimum spot size of approximately 0.3 mm. It is controlled by an IBM PC-compatible computer. With the workstation in learn mode, you use a CCD camera and joystick control to aim the laser at each solder joint. You enter the appropriate soldering parameters via the keyboard as you proceed. Subsequent soldering operations are automatic. The system is currently being demonstrated by Cambridge Interconnection Technology Ltd (Cambridge, UK, TLX 81417); the company expects the system to lead to commercial laser-soldering equipment that costs less than half what currently available laser-soldering equipment costs.—Peter Harold

16-BIT MICROPROCESSOR RUNS AT 16 MHz

NEC has recently developed a 16-MHz version of its V30 16-bit microprocessor. The new μP's program-handling capacity reportedly approaches that of 32-bit μPs, yet the processor's peripheral circuits allow it to use available 16-bit systems, including printers and disk drives. The μP uses the same command set that Intel's 8086 uses, and it's believed to be compatible with the company's V30, which runs at 8 MHz and has a 640k-byte address space. According to Japanese news reports, the 16-MHz μP is reputedly 30% faster than Intel's 80286 and Motorola's 68010. NEC is expected to begin shipping samples of the device in the next few weeks.—Joanne Clay

1k-BIT DRAM HAS 570-PSEC ACCESS TIME, DISSIPATES 13 mW

Using high-speed Josephson junctions, NEC has developed a 1k-bit dynamic RAM with an access time of 570 psec. The device dissipates 13 mW. The 4.4×4.4-mm die incorporates 10,000 niobium/aluminum oxide/niobium Josephson junctions, which are resilient to temperature cycles; they form 1000 gates and 1000 memory cells. The RAM's memory structure is organized as 1k word×1 bit. The company reduced the part's access time by means of three proprietary developments: a niobium-planarization technology, an ac/dc power source, and an ac-driven memory cell.—Joanne Clay

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MAN-2	0.5-1000	19	1.5	7	6.0	85	15.95
MAN-1LN	0.5-500	28	1.0	8	2.8	60	15.95
◊MAN-1HLN	10-500	10	0.8	15	3.7	70	15.95

††Midband $10f_L$ to $f_{u/2}$, ± 0.5dB   †1dB Gain Compression   ◊Case Height 0.3 In.
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IF	DC-500	
CONVERSION LOSS (dB)		
Mid-Band (10-250MHz)	6.3	
Total Range (1-500)	7.5	
ISOLATION (dB)	(L-R)	(L-I)
Low-Band (1-10MHz)	60	45
Mid-Band (10-250MHz)	45	40
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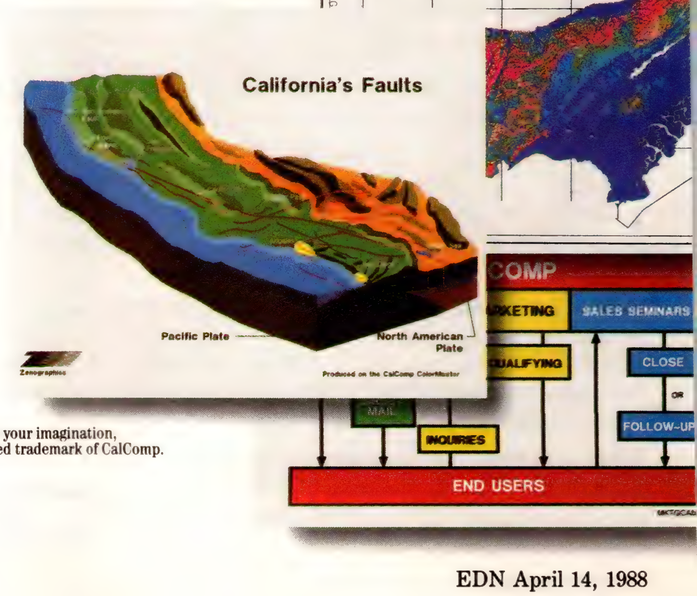

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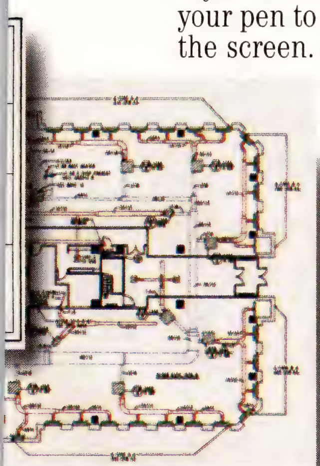

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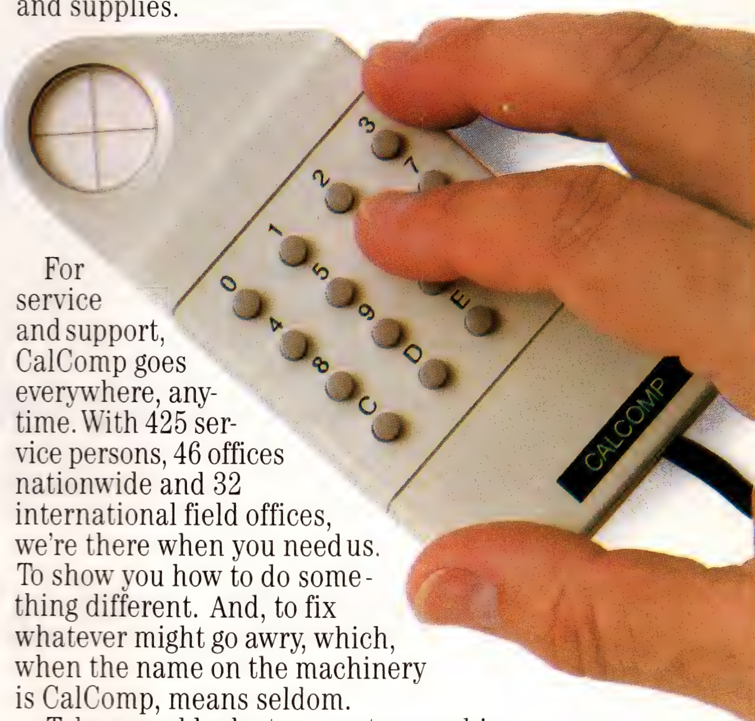

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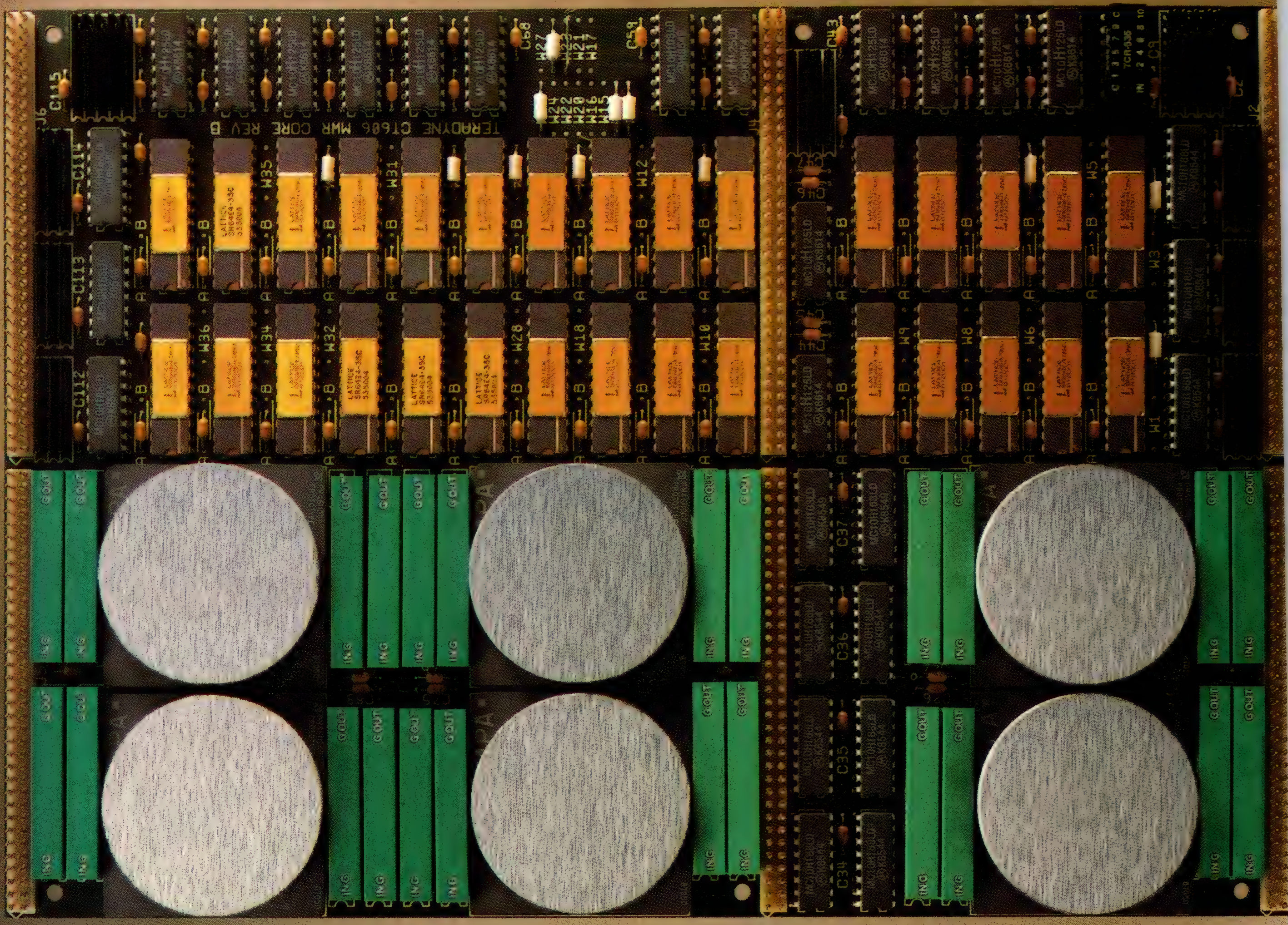

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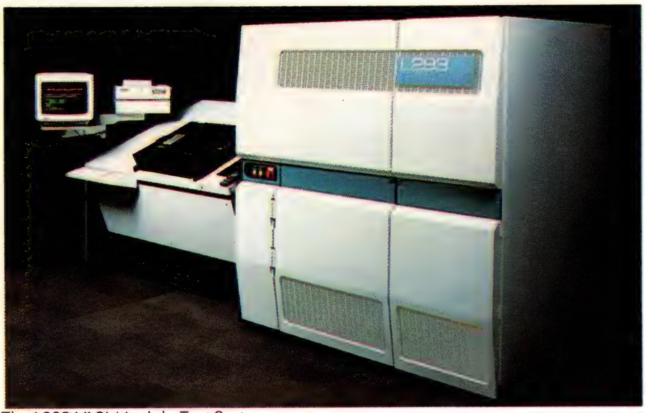

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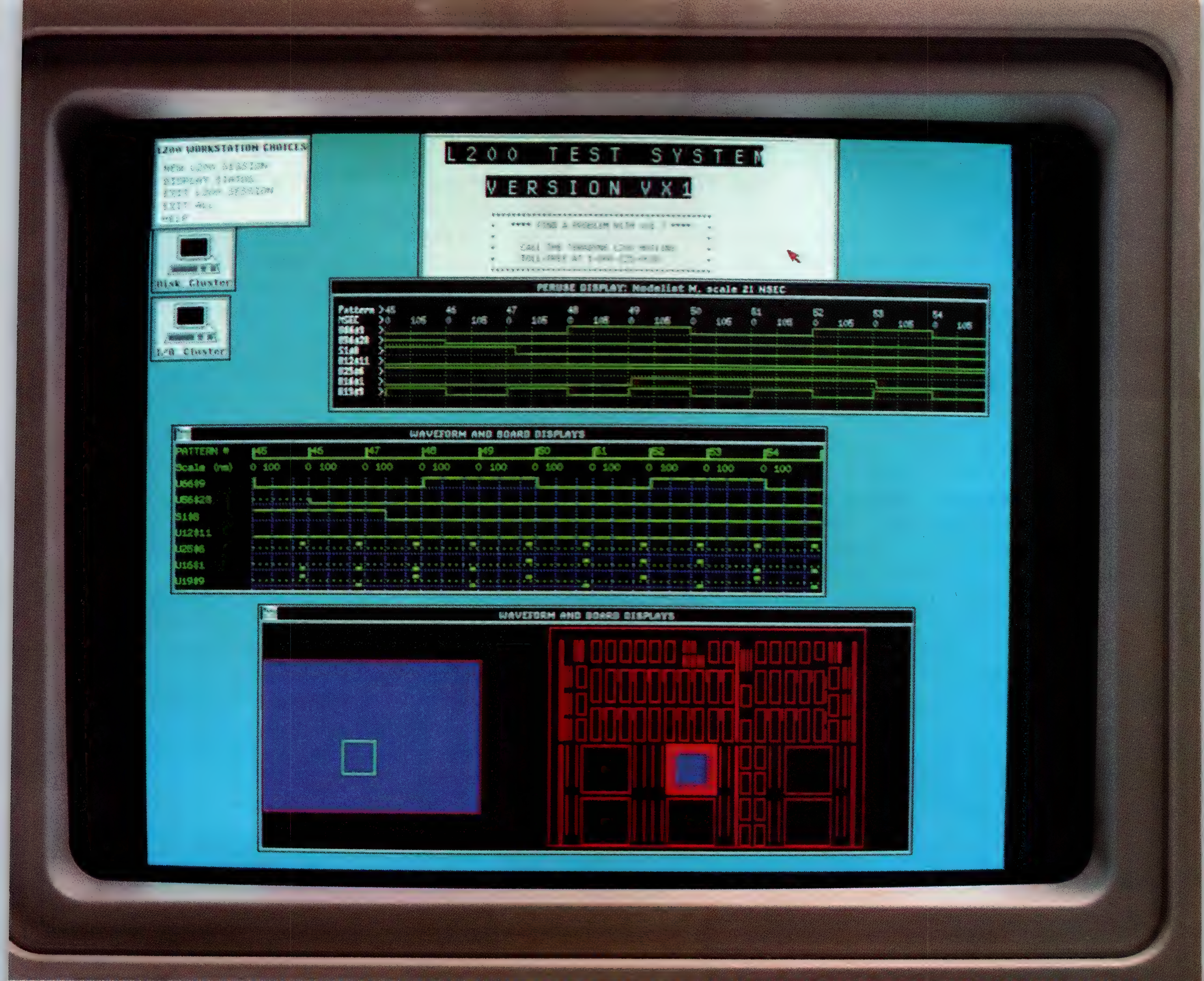

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IEEE has outlived its usefulness

I've just read Jon Titus's editorial on the IEEE election-process change ("The IEEE faces extinction," EDN, February 4, 1988, pg 53), and I want to thank him for supporting the working engineer and the Committee of Concerned EEs. I have felt as he does for some time, and have supported Irwin Feerst for the same reasons. The IEEE has taken on the wrong issues and is not doing much except paying lip service to support its membership, even in the international environment it claims to revere.

Engineers worldwide are not afforded the respect that their contributions should naturally attract, because they are not getting the recognition that organizations the size of the IEEE (and its counterparts in other disciplines) can generate. We do not have a voice with which to press our claims, and this is a media/claim-driven society. If you don't stake out your territory, you don't get it.

I would hate to see the IEEE go, but it has lived beyond its usefulness in its present incarnation. The vast majority of the engineering community does not benefit from the position that the professors and managers who run the IEEE have taken. Engineers need exactly the help Mr Titus mentioned: portable pensions, fair pay, protection as whistle-blowers, and the enforcement of tough age-discrimination rules.

The professional journals of the IEEE are so esoteric that I doubt more than a small percentage of the pages are read outside the onerous professional review process. And how can a magazine with the circulation and ad coverage of *Spectrum* lose so much money? Does the IEEE care about how the money is spent?

Unfortunately, I must ask that you not publish my name if you choose to print this letter. My company is very active in the high levels of the IEEE.

Name withheld

IEEE needs to clean house

Jon Titus's February 4 editorial about the IEEE hit the mark. I have been receiving Irwin Feerst's newsletters, and they have been quite a revelation!

I will renew my 1988 IEEE membership, with a note to the IEEE regarding my future membership in the organization. It seems to need a housecleaning from top to bottom.

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28C64 (CMOS)	**50 mA (active) 150 μA (stand-by)**	**64 bytes**	**No**	**DIP LCC PLCC**	**883 Class B**
28C65 (CMOS)	**50 mA (active) 150 μA (stand-by)**	**64 bytes**	**Yes**	**DIP LCC PLCC**	**883 Class B**

Note: All parts have read access time of 200 ns.

If you're looking for ways to cut the power needs on designs, SEEQ has some high density CMOS answers.

Our byte-wide 28C64s, for example, operate on less than 3/4 watt per Megabyte—about 1/10 the power of competitive parts. In fact, they actually use 150 μA in standby mode. That's 400 times less than NMOS devices.

With four versions to choose from, our 64K E²s give you exactly those on-chip options you need. That includes peripheral functions—like input latches, times and power up/down protection—that make it easy to interface our E²s to popular microprocessors.

These full-featured E²s outperform the competition, too. In page mode, for instance, you can write our 64Ks in 80 μsec per byte, which means you can update the entire memory in just 0.7 seconds—four times faster than the industry average.

You still get the high endurance and reliability that SEEQ E²s are known for, as well as operation over extended and full military temperature ranges.

At SEEQ, we have a lot more in store.

SEEQ Technology, Inc., 1849 Fortune Drive, San Jose, CA 95131.

Call Us On It: (408) 432-9550

seeq

E² Is Our Middle Name

SIGNALS & NOISE

I'm also sending a hefty contribution to the Committee of Concerned EEs.

Sidney Feldman
Sound Technique Inc
New York, NY

Readers' comments

- *Service economy*

"Five stars for 'The service-economy myth' [EDN, December 10, 1987, pg 53]! It's just a new term for a very old idea—serfdom." —*C F, Pinole, CA*

- *Currency confusion*

"How about [printing] prices in US currency? I don't know how much an English pound or deutsche mark is worth . . . rubles, anybody?"—*R R, Nekoosa, WI*

(Ed note: Although we do try to obtain prices in US dollars when possible, companies outside the US often prefer to quote prices in non-US currency. Because the rate of exchange fluctuates continuously, it's best to check a major newspaper; most print the exchange rates daily. Major banks can also supply this information quickly.)

And a gracious hello

Oops! You can't reach DigiBoard Inc—of St Louis Park, MN—by calling the New York, NY, phone number listed on pg 293 of EDN's February 18, 1988, issue. The correct phone number is (612) 922-8055.

WRITE IN

Send your letters to the Signals and Noise Editor, 275 Washington St, Newton, MA 02158. We welcome all comments, pro or con. All letters must be signed, but we will withhold your name upon request. We reserve the right to edit letters for space and clarity.

Gould has features you won't find at the ordinary ASIC house.

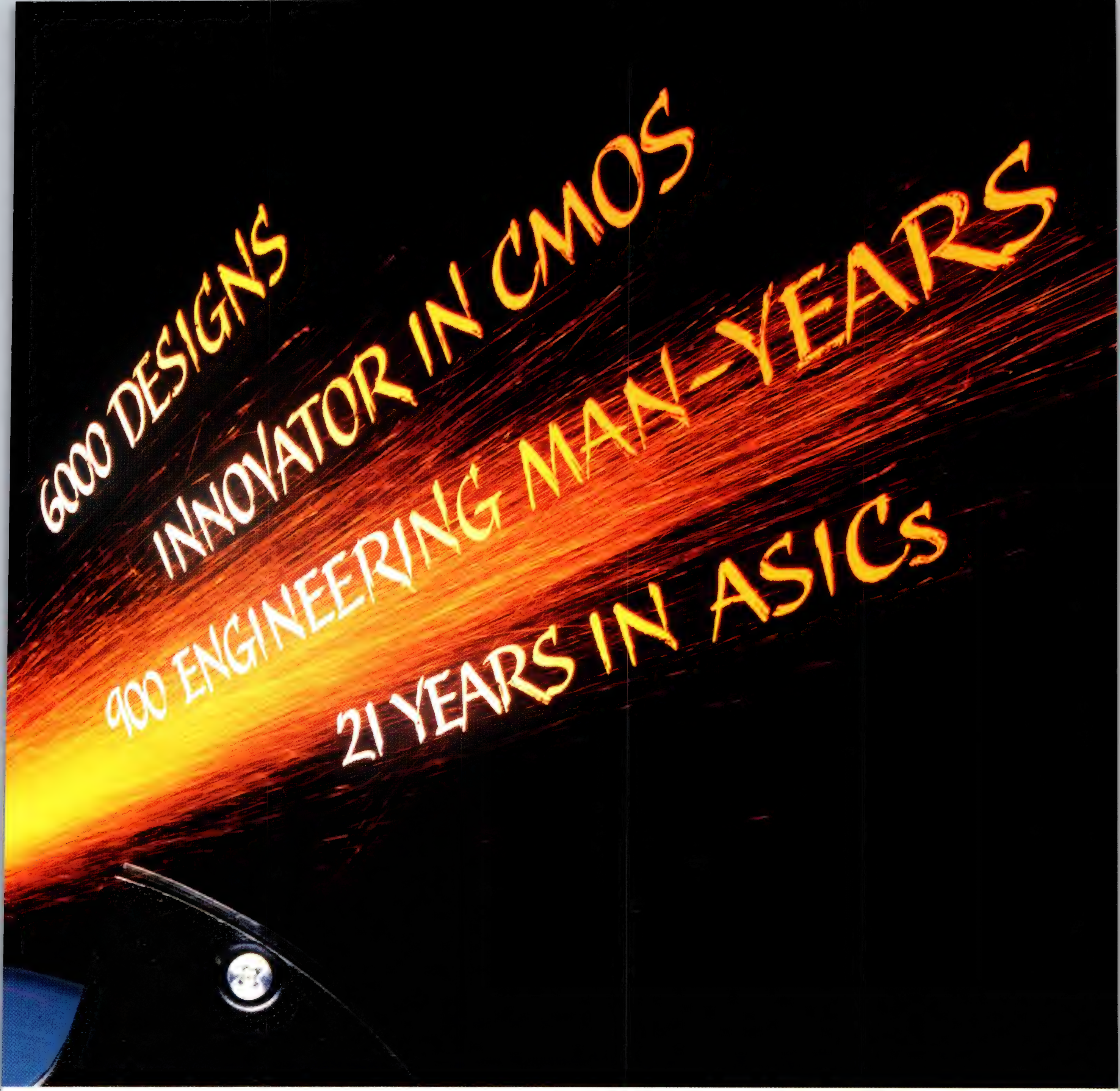
A nose to the grindstone.

What do twenty-one years as an ASIC vendor do for your customers? A lot.

Two decades give you the time you need to develop and manufacture over 6000 successful designs. The time you need to accumulate 900 man-years of engineering experience. The time you need to learn things not found in the textbooks.

That's the kind of experience Gould Semiconductors can put to work for you on every circuit you do.

Gould recognized early how valuable the combination of CMOS processes and CAD/CAE technology would be for our customers. We have been an innovator in both of these areas.



We've also had time to fully develop application-specific IC techniques that still frustrate other vendors. For instance, Gould is an acknowledged industry leader in analog/digital circuit combinations. Many ASIC producers can't even offer them.

The most important advantage to you, though, is that Gould has probably produced a design similar to yours already. We know the problems to look for and how to avoid them. In many cases, we can recommend easily incorporated features that add value to your system.

That's what twenty-one years of hard work can do for you.

Manufacturer of Gould AMI Semiconductors.

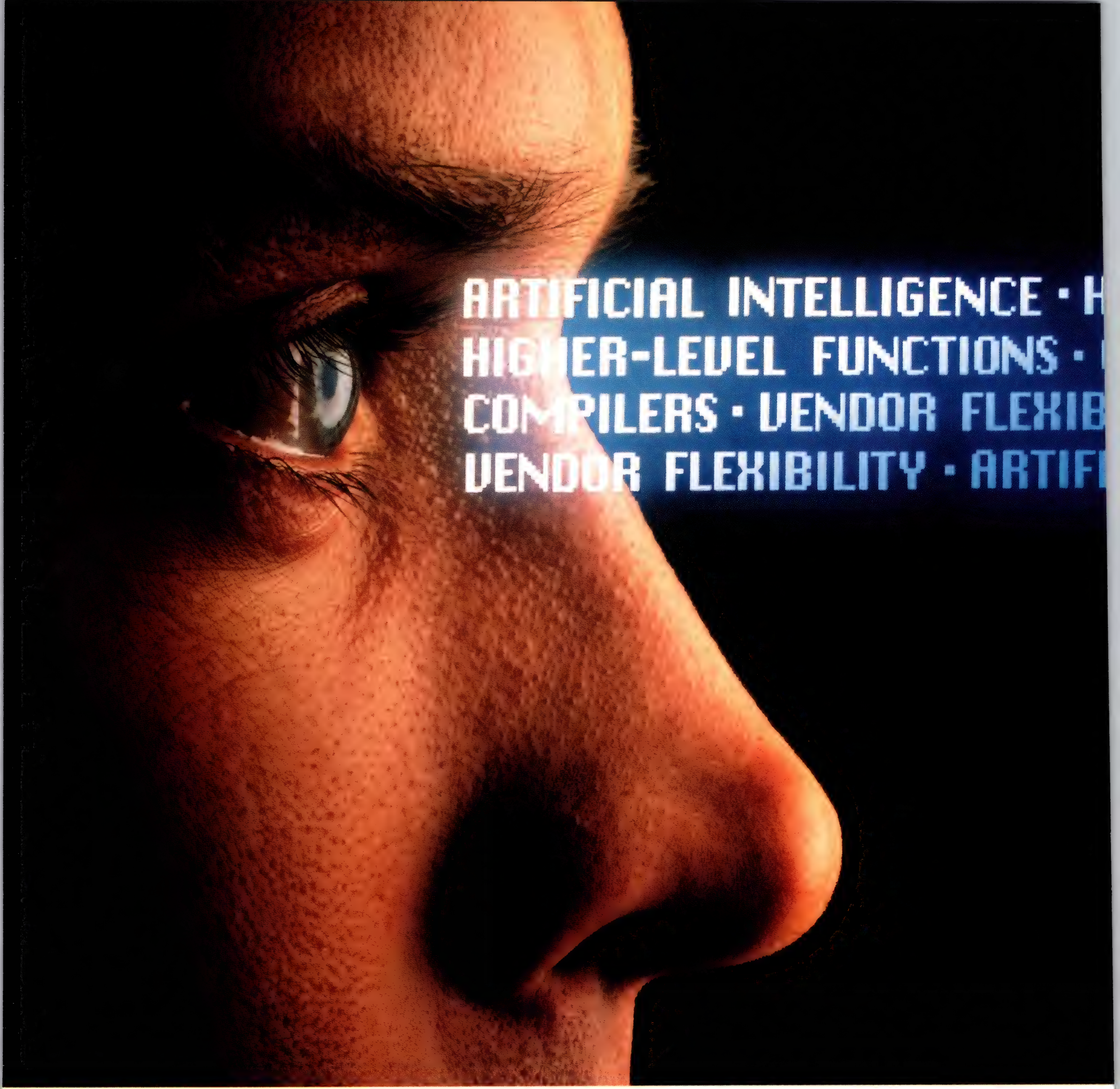
GOULD
Electronics

An ear for your problems.

All ASIC customers want essentially the same things: better system performance, lower system cost, quick development and production cycles. But every ASIC project has a different set of priorities.

Your only guarantee of success is the vendor's sensitivity to your individual needs. For two decades, Gould has listened and responded with strategies to provide the best system solution. The ASIC Continuum is one such strategy.

The ASIC Continuum provides a design solution effective for any application. There are low-cost E^2PLDs for instant prototypes and small volume production applications. Also gate arrays for fast prototyping



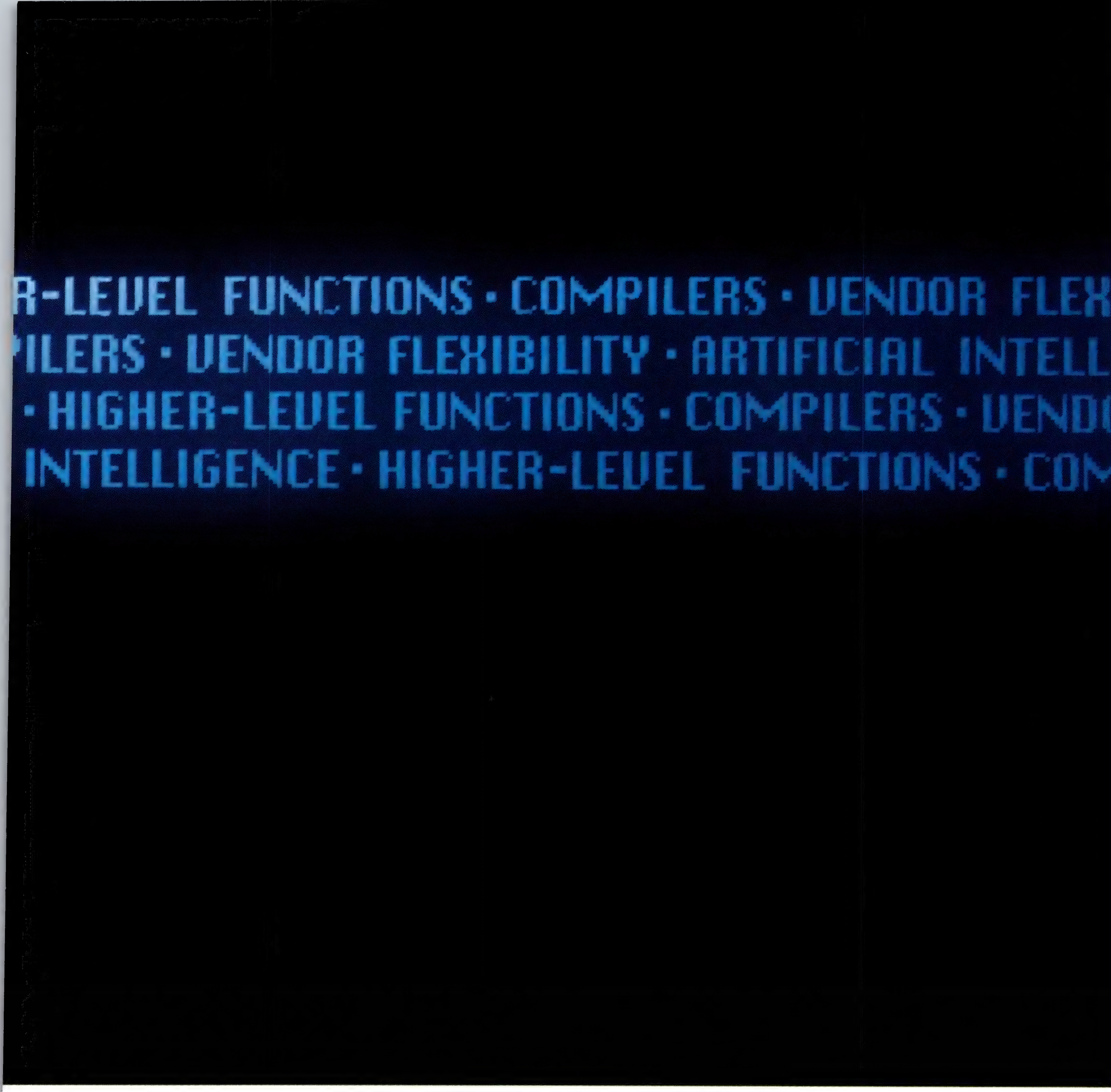
An eye on the future.

The pressure on system designers will continue to be intense. Gould has responded by cutting development spans, increasing functions and performance. And now we're using artificial intelligence (AI) to go even further.

Already Gould Expert Systems™ tools are adding value for system designers.

AI-based generators and compilers create cells in days instead of weeks. Standard cells. ROMs. RAMs. Even analog cells, like op amps and filters. And these tools are process independent, making our libraries some of the easiest to tailor to your needs.

Going a step further, megacell compilers create large custom functions (bit-slice



μPs, DSPs, etc.) in half the space of standard cells. And our newest Expert ASIC tool, Circuit Cincher,™ finds logic errors missed in simulation, so you get silicon that's right the first time.

A Gould exclusive is Netrans™ universal netlist translator. This single tool makes Gould a ready alternate source for any ASIC you do. No matter who your primary vendor is. Use any CAD/CAE system and cell library you want: our Netrans translator will convert your netlist for production at Gould. That's true vendor flexibility.

Come see how Gould's Expert ASIC tools can play a major role in your future.

Manufacturer of Gould AMI Semiconductors.

GOULD
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Gould ASIC professionals are dedicated to giving you the best system solution. And a competitive edge found nowhere else. We invite you to come meet our team. Once you see what we can do for you, you'll choose Gould hands down.

Shouldn't you find out more about us? Just return the Gould business reply card adjacent to this ad. If someone beat you to it, write: Gould Inc., Semiconductor Division, 3800 Homestead Road, Santa Clara, CA 95051, Attn: N. Greene.

If we receive your card or letter by May 31, 1988, you will be entered in a sweepstakes to *win one of ten compact disk players.** To get information faster, call 1-800-GOULD 10.

Manufacturer of Gould AMI Semiconductors.

GOULD
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*No purchase obligation is implied.

NEW FROM TEK: ANALOG FUNCTION, ARBITRARY WAVEFORM AND SWEEP GENERATION IN ONE COMPACT PACKAGE.

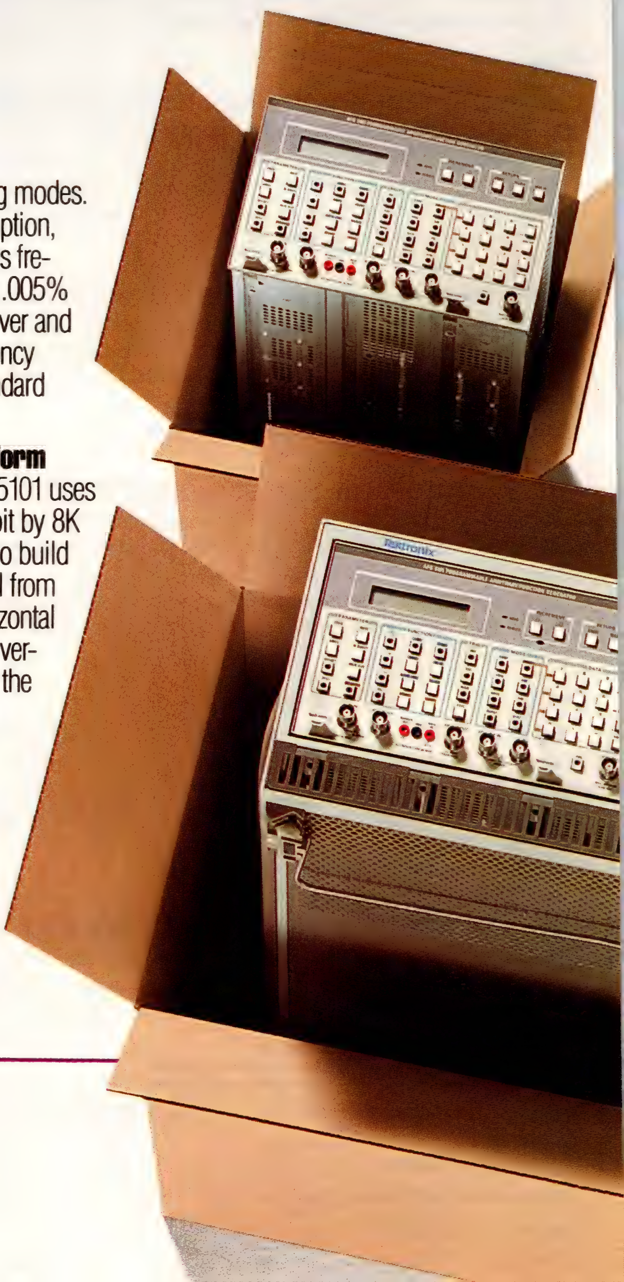
The Tek AFG 5101 Programmable Arbitrary/Function Generator is the latest addition to Tek's TM 5000 family of proven, programmable, modular test instruments.

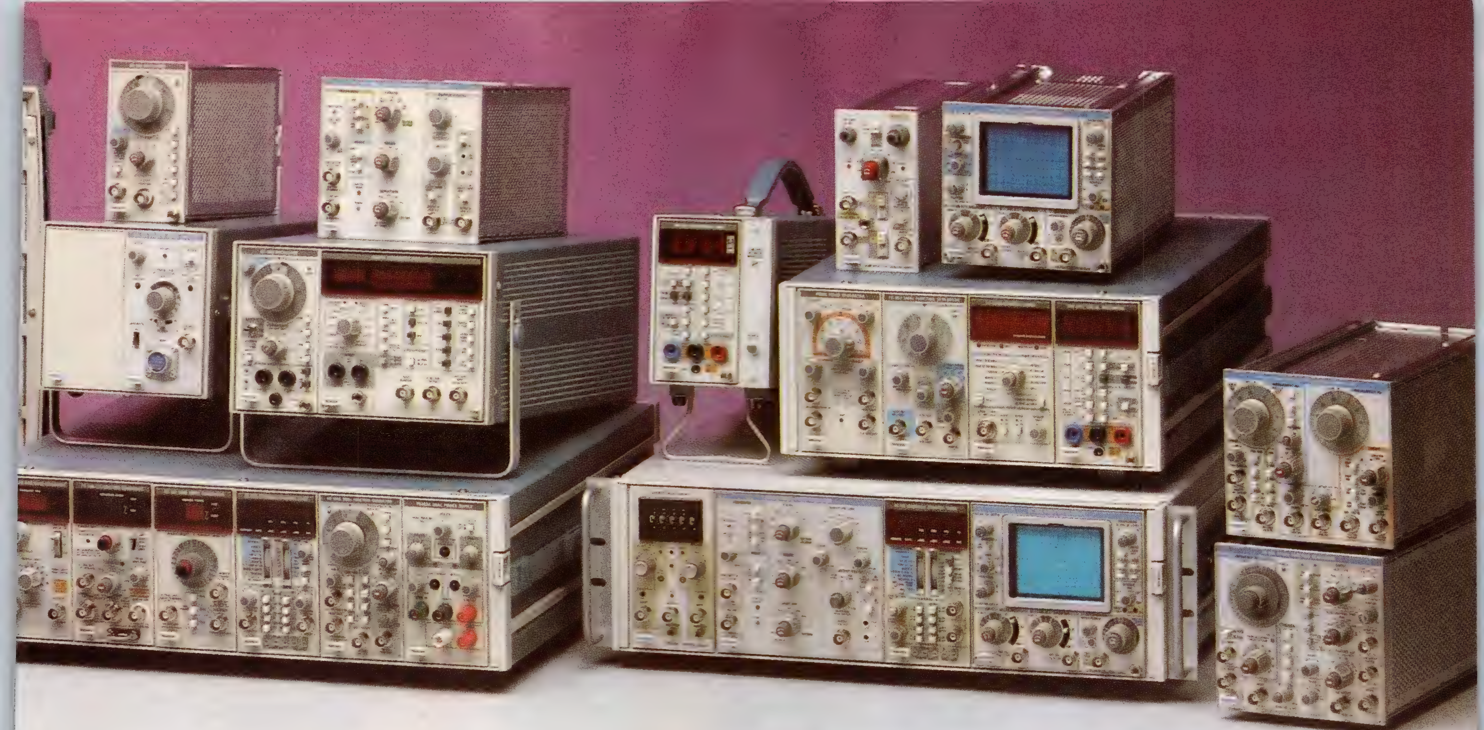
An analog function generator, the AFG 5101 can generate standard sine, square and triangle waveforms, plus dc level, with frequencies from .012 Hz to 12 MHz and amplitudes of 10 mV to 9.99V peak-to-peak, into 50 ohms. Waveforms can be continuous, triggered, gated or burst, from a full range of triggering modes.

With synthesizer option, the AFG 5101 achieves frequency accuracies to .005% (120 Hz to 12 MHz) over and above the .2% frequency accuracies in the standard instrument.

An arbitrary waveform generator, the AFG 5101 uses two independent 12-bit by 8K waveform memories to build any imaginable signal from an array of 8,192 horizontal addresses and 4,096 vertical addresses. Enter the waveforms manually from the front panel, from computer data —or select one of the unit's predefined, 1,000-point waveforms.

A sweep generator, the AFG 5101 includes linear,





logarithmic and arbitrary sweeps, with any sweep usable in continuous, triggered, gated or burst mode. Users can receive instant frequency readout of breakpoints, notches, or response anomalies.

The applications are wide open. Use the AFG 5101 to drive sensors, timers, and other R&D equipment. To simulate metal stress or vibration characteristics. To teach waveform theory to students. And much more.

Easy waveform editing capabilities …non-volatile storage of up to 99 front panel settings and two 8K point waveforms…binary block GPIB transfer…two waveform memories plus third, execution memory—these and other features make the AFG 5101 a simple, powerful and uniquely flexible tool.

AVAILABLE IN THREE CONFIGURATIONS.
The first triple-duty test instrument of its kind, it is available in monolithic (AFG 5501), as a plug-in (AFG 5101), or in our Programmable Arbitrary Stimulus/Measurement package (EBS 5002).

Take 10% off with our package offer. Order the AFG 5101 in our Programmable Arbitrary Stimulus/ Measurement package and take 10% off catalog prices.

For the full story on these and other Tek modular instruments, call 1-800-426-2200. Or contact your nearby Tektronix field office.

(Center photo) The AFG 5101 can be ordered in either monolithic version, top right, or as a plug-in for the TM 5000 series mainframes, top left. Or, combine it with the DM 5010 4.5 Digit Multimeter and DC 5009 135 MHz Digital Counter within a TM 5006 mainframe (EBS 5002), as shown at bottom, and take 10% off the normal catalog price.

Tektronix
COMMITTED TO EXCELLENCE

CIRCLE NO 26


MOTOROLA

Silicon talks.

The most popular communication protocols are available in silicon to simplify your designs.

With protocol controllers from Motorola, designing data communications is easier and their markets are more universal than ever before. Standard protocols are built into silicon so there's no need to burden your host. Built with Motorola's proven HCMOS technology, they offer the reliability you've come to expect and the advanced designs you demand.

Communicate now with our family of protocol controllers.

Our MC68000 Family offers three different protocol controllers to handle all your data communication needs; whether it's across the building or around the world there's a Motorola device that will make your job easier. With our '68000 Family you can choose the protocol and system designs that get you on line quickly and economically.

X.25 Protocol Controller 1984 CCITT X.25 LAPB.

The MC68605 Protocol Controller (XPC) implements the 1984 CCITT Recommendation X.25 Link Access Procedure Balanced (LAPB) for U.S. and European T1 applications. By generating link-level commands and responses, the XPC relieves the host processor of communication link managerial tasks. It's also fully DDN and Telenet certifiable.

Our XPC features an optional transparent mode which allows the implementation of other HDLC-based protocols, with user generation of all frames. The XPC handles full-duplex synchronous serial data rates up to a maximum 10 Megabits Per Second (Mbps) for high-speed computer links.

Multi-link LAPD Controller CCITT Q.920/Q.921 LAPD.

The MC68606 Multi-link LAPD (MLAPD) Protocol Controller fully implements CCITT Recommendation Q.920/Q.921 Link Layer Access Procedure (LAPD) protocol for ISDN networks. The MLAPD is designed to handle both signalling and data links in high-performance ISDN primary rate applications.

This VLSI device provides a cost-effective solution to ISDN link-level processing with simultaneous support for up to 8K logical links. The MC68606 is an intelligent communications protocol controller compatible with AT&T specifications for ISDN devices and features low power consumption and high performance, with an aggregate data rate in excess of 2.048 Mbps.

Token Bus Controller IEEE 802.4 MAC.

The MC68824 Token Bus Controller (TBC) is the only single-chip solution to implement the IEEE 802.4 Media Access Control (MAC), specified by Manufacturing Automation Protocol (MAP). The TBC implements four levels of message priority and the Request With Response (RWR) frame type to meet the real-time needs of factory floor communications and MAP 3.0.

The TBC conforms to the IEEE 802.4G standard MAC to Physical layer serial interface to support broadband, carrierband, and fiber optic networks. The TBC's low power consumption coupled with its extended temperature range versions make it ideally suited for factory automation applications.

Token Bus Frame Analyzer Software speeds development of token bus networks.

The MC68KTBFA Token Bus Frame Analyzer Software (TBFA) is a real-time software tool that speeds development of token bus networks. The TBFA keeps track of statistics while monitoring network performance. By using the simple menu-driven interface, the user can define triggers to selectively store and display frames, creating a powerful tool for network analysis.

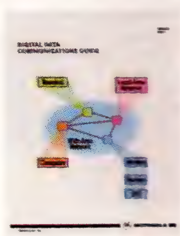
The TBFA is a set of four EPROMs which runs on a VMEbus MVME372 Token Bus Controller board and requires a modem, a VT100 terminal, and a power source. The cost-effective TBFA sells for about one-tenth the cost of existing token bus protocol analyzers.

For more information.

For more information about solutions to protocol controller applications contact your Motorola sales office. For technical literature on any of the MC68000 Family of protocol controllers, please complete and submit the coupon below.

We're on your design-in team.

MOTOROLA



Write To: Motorola Ltd., European Literature Centre, 88 Tanners Drive
Blakelands, Milton Keynes MK14-5BP, United Kingdom

Please send me information on the following:

- ☐ MC68606 Multi-link LAPD Protocol Controller
- ☐ MC68824 Token Bus Controller
- ☐ MC68KTBFA Token Bus Frame Analyzer
- ☐ MC68605 Protocol Controller (X.25)

335EDN041488

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Philips single-chip 8-bit microcontrollers help turn your product ideas into commercial reality as quickly, easily, and economically as possible.

You can work with CMOS, NMOS or bipolar microcontroller families incorporating a comprehensive list of derivatives. These are backed by a wide range of I^2C-bus peripherals to help implement your design. And we've made it as easy as possible to choose the right microcontroller for your application. We provide a choice of 64 to 256-byte RAM, 1K to 16K ROM, on-board functions like ADC, EPROM, timers and I^2C-bus interface. We offer bond-out and EPROM versions and you can also select from a variety of industry standard packages; DIL, SO, PLCC, QFP or PGA – with temperature ranges as broad as −40°C to 110°C.

Philips, Europe's leading manufacturer of 8-bit microcontrollers, is a major force in electronics world-wide. When your partner is Philips you can move more confidently and effectively from ideas to reality.

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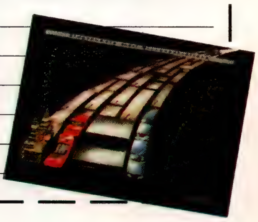

EDN041488

or single-chip 8-bit microcontrollers.
ne name is Philips.

PHILIPS

CALENDAR

Troubleshooting Microprocessor-Based Equipment and Digital Devices (seminar), Cincinnati, OH. Micro Systems Institute, 73 Institute Rd, Garnett, KS 66032. (800) 247-5239; in KS, (913) 898-4695. April 25 to 28.

Speech Tech '88, New York, NY. Media Dimensions, 42 E 23rd St, New York, NY 10010. (212) 533-7483. April 26 to 28.

Systems Engineering for Engineers and Managers, Los Angeles, CA. N B Reilly & Associates, 4220 S Harbor Blvd, Suite 305, Oxnard, CA 93030. (805) 985-7413. April 26 to 28.

Analog Applications (seminar), San Diego, CA. Precision Monolithics Inc, (800) 843-1515. April 28.

Uninterruptible Power Systems: Design, Selection, and Specification (short course), Milwaukee, WI. Center for Continuing Engineering Education, University of Wisconsin-Milwaukee, 929 N 6th St, Milwaukee, WI 53203. (414) 227-3120. April 28 to 29.

Analog Applications (seminar), San Jose, CA. Precision Monolithics Inc, (800) 843-1515. April 29.

AutoCAD Expo, Chicago, IL. Autodesk, 2320 Marinship Way, Sausalito, CA 94965. (415) 332-2344. May 2 to 5.

Midwest Electronics Expo, St Paul, MN. MG Expositions Group, 1050 Commonwealth Ave, Boston, MA 02215. (617) 232-3976. May 3 to 5.

CASExpo Spring, Dallas, TX. CASExpo Spring Coordinator, 3825-I South George Mason Dr, Falls Church, VA 22041. (703) 845-1657. May 3 to 6.

Introducing The SCHEMA Family Of Integrated CAE Solutions.

Omation, the originators of SCHEMA I and II, announces two new solutions in the SCHEMA family of integrated software for the professional PCB design engineer — *SCHEMA PCB LAYOUT* and *SCHEMA AUTOROUTER*.

Now, you can enter a schematic using SCHEMA II, then process it with SCHEMA-PCB and SCHEMA-ROUTE into a finished printed circuit card — *from start to finish in one easy step*.

SCHEMA-PCB and SCHEMA-ROUTE operate on an IBM personal computer or compatible, yet they offer all the features of design work-stations costing $50,000 or more *for a fraction of the cost*:

- Boards of over 400 equivalent ICs, up to 32″ × 32″, and up to 30 layers
- Resolution on placement and tracking of 1 mil
- Autoplacement
- Selectable track width and pad size/shape (250 increments of 1 mil each)
- Integrated schematic input and back annotation
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- Autorouting with 4 separate algorithms for accuracy
- Complete manufacturing kit output
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As always, each member of the SCHEMA family of products comes with a *30-Day Money Back Guarantee*.

Capture your solutions by calling us Toll Free: **1-800-553-9119** (in Texas, 214-231-5167). Ask us about our SCHEMA Family Demo Evaluation Kit.

OMATION
1210 E. Campbell Rd., Suite 100
Richardson, Texas 75081

CIRCLE NO 32

CALENDAR

Analog Applications (seminar), Los Angeles, CA. Precision Monolithics Inc, (800) 843-1515. May 4.

Pittsburgh Conference on Modeling and Simulation, Pittsburgh, PA. William Vogt or Marlin Mickle, 348 Benedum Engineering Hall, University of Pittsburgh, Pittsburgh, PA 15261. May 5 to 6.

Worst-Case Circuit Analysis (seminar), Washington, DC. Design and Evaluation, 1000 White Horse Rd, Suite 304, Voorhees, NJ 08043. (609) 770-0800. May 9 to 11.

Electro '88, Boston, MA. Electronic Conventions Management, 8110 Airport Blvd, Los Angeles, CA 90045. (800) 421-6816; in CA, (213) 772-2965. May 10 to 12.

EMC Expo, Washington, DC. Karen Smith, EMC Expo, Box D, Gainesville, VA 22065. (703) 347-0030. May 10 to 12.

Analog Applications (seminar), Chicago, IL. Precision Monolithics Inc, (800) 843-1515. May 13.

DOD-STD-2167A and DOD-STD-2168—Defense System Software Development (seminar), Washington, DC. David Maibor Associates, Box 846, Needham, MA 02194. (617) 449-6554. May 16 to 17.

IEEE Custom Integrated Circuits Conference, Rochester, NY. Roberta Kaspar, 20 Ledgewood Dr, Rochester, NY 14615. (716) 865-7164. May 16 to 19.

0 to 60 in 5 seconds

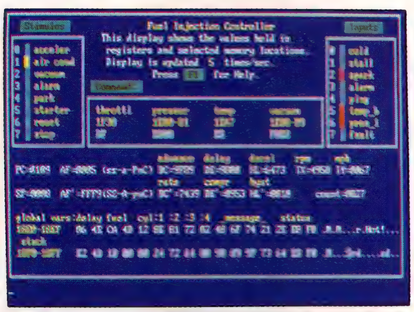
with new UniLab 8620 analyzer-emulator.

■ 64Kbytes from hard disk in 5 seconds. That's moving. But today you've got to be fast just to stay in the race for better microprocessor designs.

■ The secret is a new, high-speed parallel interface: the Orion bus. Which zips data between your PC/AT and the 8620 analyzer-emulator, breaking the RS-232 bottleneck.

■ The 8620 with O-bus gives you complete program diagnosis — and solutions — in real time. For more than 150 different microprocessors. Using **the same command set** environment.

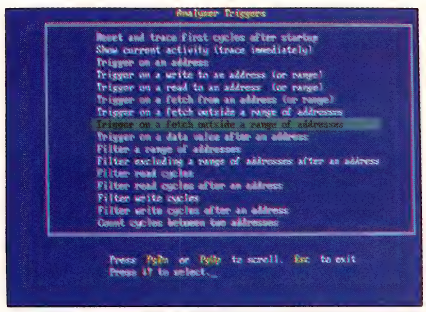
■ A generous 2730 trace-cycle buffer with selective filtering lets you cut through the clutter and display just the traces you wish. And you get 1μsec resolution in program time measurement. Plus continuous InSight monitoring of your program's key functions as they are performed.



InSight Display. InSight blends analyzer-emulator techniques to give you continuous, real time monitoring of key processor functions. And still services user interrupts. It displays changing register contents, I/O lines, ports, user-defined memory windows. With your own labels.

■ On top of that, you get UniLab's trademark ability to debug by symptom, not just by breakpoint and single step. And, to help you complete the job on time, on the spot, a stimulus generator and EPROM programmer are included.

■ Ease of use, another Orion trademark, is also built in. So you have all the familiar features and formats you're used to working with. It doesn't matter if your project is a single chip controller or complex 16-bit microprocessor, the 8620 is the top price/performance analyzer-emulator that does it all. At just $4380. With processor Personality Paks typically $550 each.



Analyzer Triggers. Commonly used triggers can be selected quickly from a list of standard and user-defined triggers.

■ UniLab 8620. Fast-lane debugging that gets you to market quicker.

Call toll-free: 800/245-8500.
In CA: 415/361-8883

ORION
INSTRUMENTS

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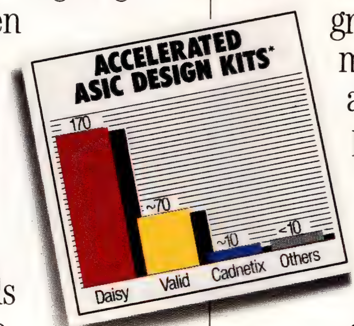
702 Marshall St., Redwood City, CA 94063
TLX 530942 FAX 415/361-8970
Computer Integrated Instrumentation

CIRCLE NO 34

DO YOU HAVE WHAT IT TAKES TO MAKE IT BIG IN ASICS?

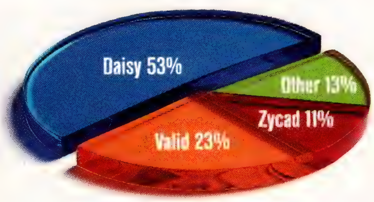
Not long ago, designing ASICs wasn't even part of your job. Now it's the part everyone's counting on.



That's where Daisy comes in.

Daisy CAE tools are used by more ASIC designers than any other CAE workstations.

Because from schematic creation through post-layout



Simulation accelerator market share. Source: Prime Data, 1985 and 1986 unit shipments.

simulation, Daisy has what it takes to keep ASICs on time and on budget.

For example, our MegaLOGICIAN™ simulation accelerator is seamlessly integrated with the schematic, so you can locate and correct design problems interactively. That means faster debugging and more time to improve the quality of your design. Plus no other accelerator is as well supported, with more than 170 design kits supplied by 70 different vendors. So you can build productivity instead of libraries.

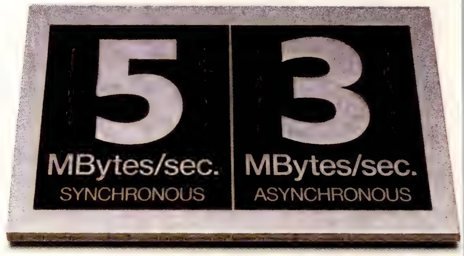
Which may explain why more MegaLOGICIANs are in use today than all other accelerators combined.

Speaking of combining, you

*Based on minimum 10x performance improvement compared to 32-bit workstations. Source for design kit estimates: VLSI Systems Design's Semicustom Design Guide, 1987.

NCR keeps standards

Finally, a cure for SCSI overheadaches.



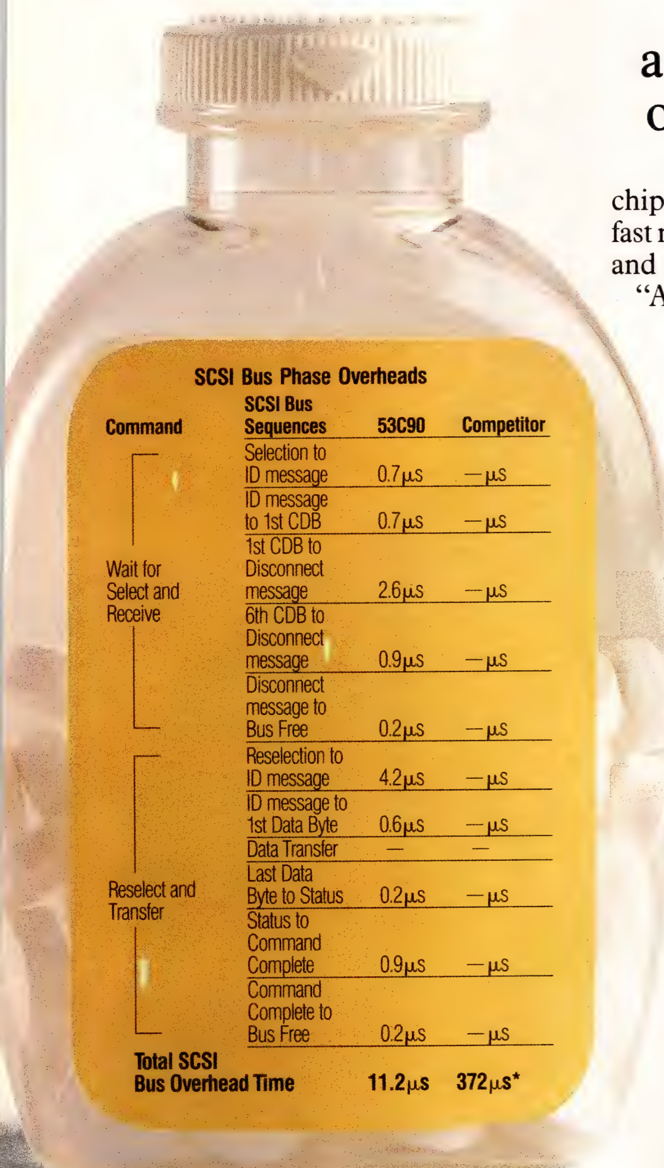
NCR's 53C90 is the only chip that can give you fast, fast, fast relief from overheadaches . . . and that includes the newest "A" and "6250" versions from the competition.

Using combination commands, dedicated sequential logic and dual-ranked registers for command pipelining, the 53C90 is magnitudes faster on and off the bus. Plus NCR implements complex bus sequencing in hardware, not time-wasting software.

Here's our benchmarks. But run your own and you'll see the other guys cause overheadaches, we cure them.

How our data transfer rates rate.

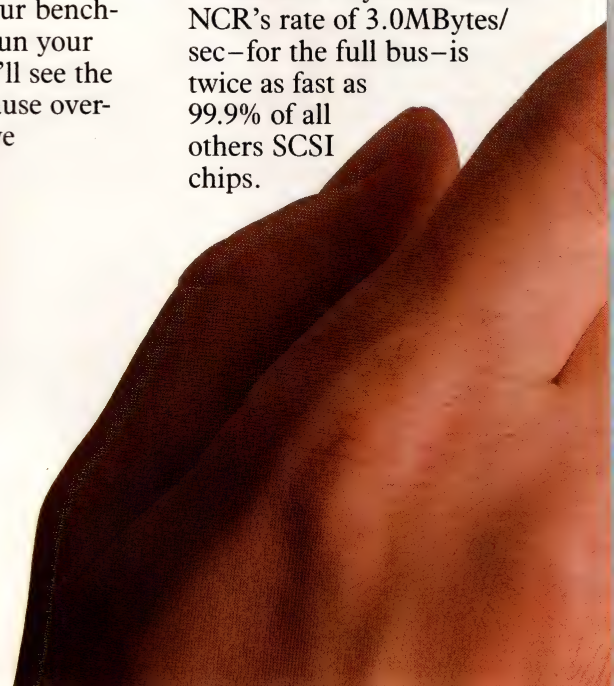
You either got great numbers. Or you don't. We got 'em. NCR 53C90 delivers the SCSI bus maximum of 5.0 MBytes/sec synchronous at 25 MHz for the full length of the bus. That's at least 1MByte/sec better than most competitive chips can do, without migraine-sized overheadaches. Asynchoronous? NCR's rate of 3.0MBytes/sec–for the full bus–is twice as fast as 99.9% of all others SCSI chips.



SCSI Bus Phase Overheads

Command	SCSI Bus Sequences	53C90	Competitor
Wait for Select and Receive	Selection to ID message	0.7µs	—µs
	ID message to 1st CDB	0.7µs	—µs
	1st CDB to Disconnect message	2.6µs	—µs
	6th CDB to Disconnect message	0.9µs	—µs
	Disconnect message to Bus Free	0.2µs	—µs
Reselect and Transfer	Reselection to ID message	4.2µs	—µs
	ID message to 1st Data Byte	0.6µs	—µs
	Data Transfer	—	—
	Last Data Byte to Status	0.2µs	—µs
	Status to Command Complete	0.9µs	—µs
	Command Complete to Bus Free	0.2µs	—µs
Total SCSI Bus Overhead Time		**11.2µs**	**372µs***

*Electronics Magazine August 20, 1987 Pg. 65



New high performance PC-based emulators from HP.

Introducing the HP 64700 Series emulators. Low-cost, entry-level, PC-based emulators with features you won't find with any others in the price range—or even higher. The HP 64700s deliver unmatched capability, ease-of-use, measurement power, flexibility, and reliability... plus HP support.

While the HP 64700s are tailored to meet the needs of individual engineers and small design teams, they'll perform equally well for large teams working on complex projects.

The rapidly expanding family of HP 64700 emulators provide real-time, transparent emulation at full processor speeds with no wait states. The PC user interface gives a new meaning to the term "friendly" with features like multiple windows, single-letter keystroke command entry, access to symbols for powerful debugging capability, timing diagrams, and on, and on, and on. The experienced user as well as the beginner will appreciate how easy these emulators are to work with.

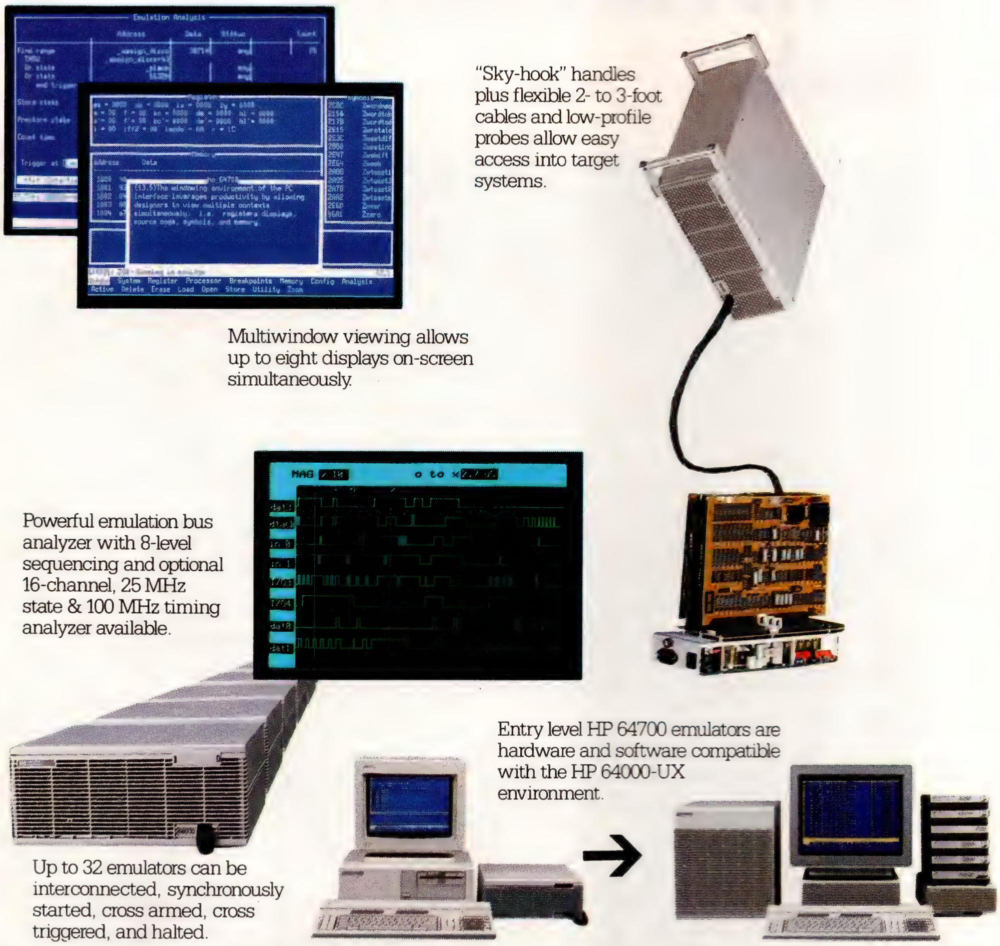
In addition to the features shown above, there are lots of others that put the HP 64700s in a class by themselves. To name a few: function with IBM-PC, HP Vectra and compatibles, RS-422 high-speed serial

CIRCLE NO 36

we never stop asking

"What if..."

You could spend a lot more and get a lot less.



interface for superior download and upload speed, code coverage analysis for efficient software testing and design, host-independent portability, and compatibility with popular absolute file formats such as Tektronix and Intel hexadecimal and Motorola S record.

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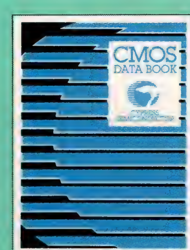

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EDITORIAL

There is strength in partnerships

If the recent Buscon show in Anaheim, CA, is any indication, the bus-level computer business is maturing. More and more, suppliers and customers are treating each other like partners rather than just buyers and sellers. These partnerships aren't the strategic alliances you read about in the *Wall Street Journal* or *Business Week*, and they don't involve lawyers and lengthy agreements for sharing technologies or designs. Instead, they represent changing attitudes on the part of manufacturers and customers alike. Manufacturers are dropping the take-it-or-leave-it attitude. Customers, instead of trying to grind a supplier down to the lowest possible price, are now more concerned with quality, reliable sources of supplies, and service.

Under such partnership arrangements, progressive companies try to provide a complete line of products to meet as many of their customers' needs as possible. For example, a traditional manufacturer of computer-board card cages wishing to remain competitive must now offer a product line that includes enclosures, power supplies, backplanes, and connectors, as well as card cages. Customers want customized products, too, so successful manufacturers pay attention to special requirements and supply the needed products. After all, that's what partners are for. It's no longer sufficient for a supplier to offer a limited range of products.

Likewise, customers look to manufacturers to solve as many of their problems as possible. Customers will shun companies that simply manufacture a few add-in computer boards, for example. The customers want more than just boards. They want to buy software drivers, compilers, operating systems, and debugging tools that will get the boards up and running as quickly as possible.

Although it might seem like I'm stretching the point, coworkers can act like partners, too. Perhaps that's what gives some of our foreign competitors such strength. The technicians are partners with the engineers, the engineers are partners with their group leaders, and so on. Each group acts like a "buyer" and a "seller." For instance, the engineers buy technical assistance from the technicians, and sell designs to management. Each group in the partnership strives to offer as broad a line of talents and services as possible. Whether we're describing companies or people, the future belongs to the general "suppliers" who offer an extensive line of quality products or services and to the "customers" who put quality, reliability, and service above a few cents shaved off a price.

Jon Titus

Jon Titus
Editor


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the first core-based 16-bit CMOS MCU.

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OKI system technologies have implemented a true macro-cell approach with the 66301. Essentially a static part, this MCU presents a whole new level of integration. On board, in addition to the 16-bit CPU: 16K bytes of ROM (48K bytes external). 512 bytes of built-in RAM (512K bytes external).

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With the 66301 on line (and an E^2 version available soon), OKI's exclusive **NXC** introduces a new generation of high-level integration — for your most demanding automotive, telecomm and instrumentation system requirements.

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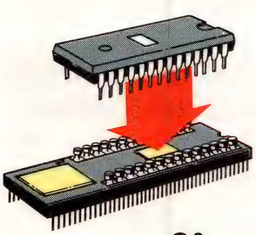
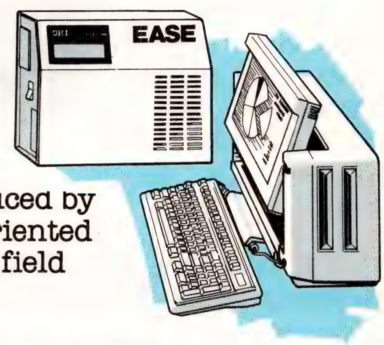
OKI's total commitment to development ease and support gives you a headstart in **NXC** microcomputing.

We can provide a special development version of the 66301 chip — built to accept an EPROM piggyback. To check out your design in realtime, snap on your coded memory. This allows you to keep burning code variations into inexpensive EPROMs, until you get a working prototype ...at a very minimal cost.



Of course, OKI's 66301 MCU is solidly backed with a full-scale development system. For realtime in-circuit emulation (ICE), use the **NXC** EASE system. The portable EASE package includes your ICE hardware, user's manual, plus complete assembler and debugger software for both MSDOS and VMS. With a compatible high-efficiency C-Compiler option as well. All available from OKI. All part of the **NXC** solution to high-end multitasking applications, produced by the most system-oriented technologies in the field today.



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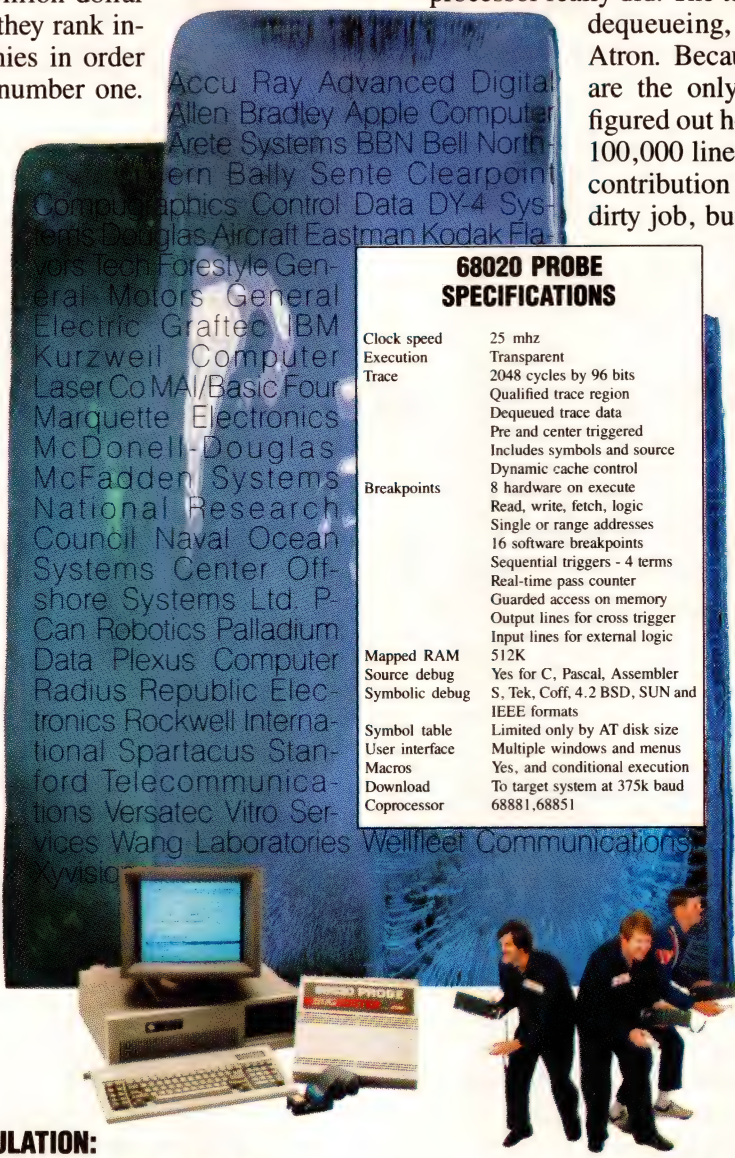
WHO YA GONNA CALL TO ICE 68020 BUGS? ATRON BUGBUSTERS!

We recently received a competitive analysis written by a billion-dollar competitor of ours. In it, they rank in-circuit emulation companies in order of importance. We were number one.

SO WHO'S ATRON?

Today, Atron is the number-one supplier of hardware-assisted software debuggers for 8088/80286/80386-based PCs. Nine of the top ten software packages were written by Atron customers. Everybody from AST to Borland to Oracle to Zenith. Now, we can make the same claim in the 68020 marketplace.

Everybody from Apple (MAC IIs) to Wellfleet (datacom) will attest to the superiority of Atron's 68020 debugging technology. One Atron customer even said, "We sent our non-Atron ICE unit out several months ago for repairs; nobody around here seems to know or care if it's back yet. The Atron unit is the tool of choice."



68020 PROBE SPECIFICATIONS

Clock speed	25 mhz
Execution	Transparent
Trace	2048 cycles by 96 bits Qualified trace region Dequeued trace data Pre and center triggered Includes symbols and source Dynamic cache control
Breakpoints	8 hardware on execute Read, write, fetch, logic Single or range addresses 16 software breakpoints Sequential triggers - 4 terms Real-time pass counter Guarded access on memory Output lines for cross trigger Input lines for external logic
Mapped RAM	512K
Source debug	Yes for C, Pascal, Assembler
Symbolic debug	S, Tek, Coff, 4.2 BSD, SUN and IEEE formats
Symbol table	Limited only by AT disk size
User interface	Multiple windows and menus
Macros	Yes, and conditional execution
Download	To target system at 375k baud
Coprocessor	68881,68851

25-MHZ, REAL-TIME, EMULATION: SOONER OR LATER, YOU KNOW YOU'LL NEED IT.

Why invest in a slower emulator (especially one that costs more)? Some bugs only occur in real time, and you know your next design will be 25 mhz. Before Atron's state-of-the-art design, there was no such thing as a 25-mhz emulator. There still isn't another one anywhere near our price.

PROBE CAN TRACE IT THROUGH THE PIPELINE, SO YOU WON'T LOSE YOUR MIND.

The 68020 has an on-board pre-fetch pipeline. Without Atron's 68020 PROBE, your best software engineer will spend a lot of time figuring out which instructions actually execute, and then, which bus cycles go with those instructions. The 68020 PROBE eliminates all these tedious mental translations and displays what the processor really did. The technology, called pipeline dequeueing, is only available from Atron. Because the Atron bugbusters are the only ones anywhere who've figured out how to do it. And it took us 100,000 lines of code. Consider it our contribution to your sanity. (It was a dirty job, but somebody had to do it.)

LET THE SOURCE BE WITH YOU.

Why spend all day doing mental translations between your C source code and the machine code in your target? These tedious operations are eliminated with Atron's source-level debugging capabilities.

Since PROBE uses a PC AT as its instrumentation chassis, you can get compiled code to its target via Ethernet, VAXNet, SUNNet, SCSI or RS-232. And whether you are compiling on a PC, a workstation or a VAX, Atron supports more object-module formats than anybody else (see specification box).

YOU'LL BE A BELIEVER AFTER A SHORT DEMONSTRATION.

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☐ Please send me your 36-page 68020 PROBE user's guide, with its command summary and examples of use.

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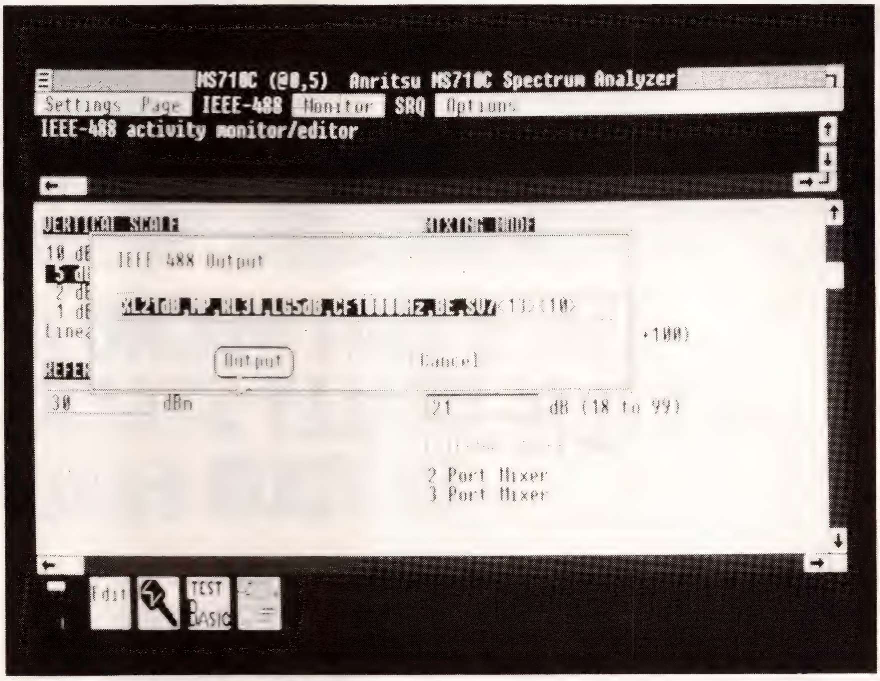
EDN041488

Program-generation tools for PCs ease IEEE-488 system integration

Peter Harold, *European Editor*



***This custom device window from the instrument library** for Summation's Testwindows typifies the approach to instrument control used in many IEEE-488 programming packages. You set up an IEEE-488 instrument by selecting the appropriate instrument setting from an on-screen function menu. The inset window illustrates the IEEE-488 programming string that is automatically generated from your selections. You can send the string directly to the instrument to test it, and then incorporate it in your Basic program.*

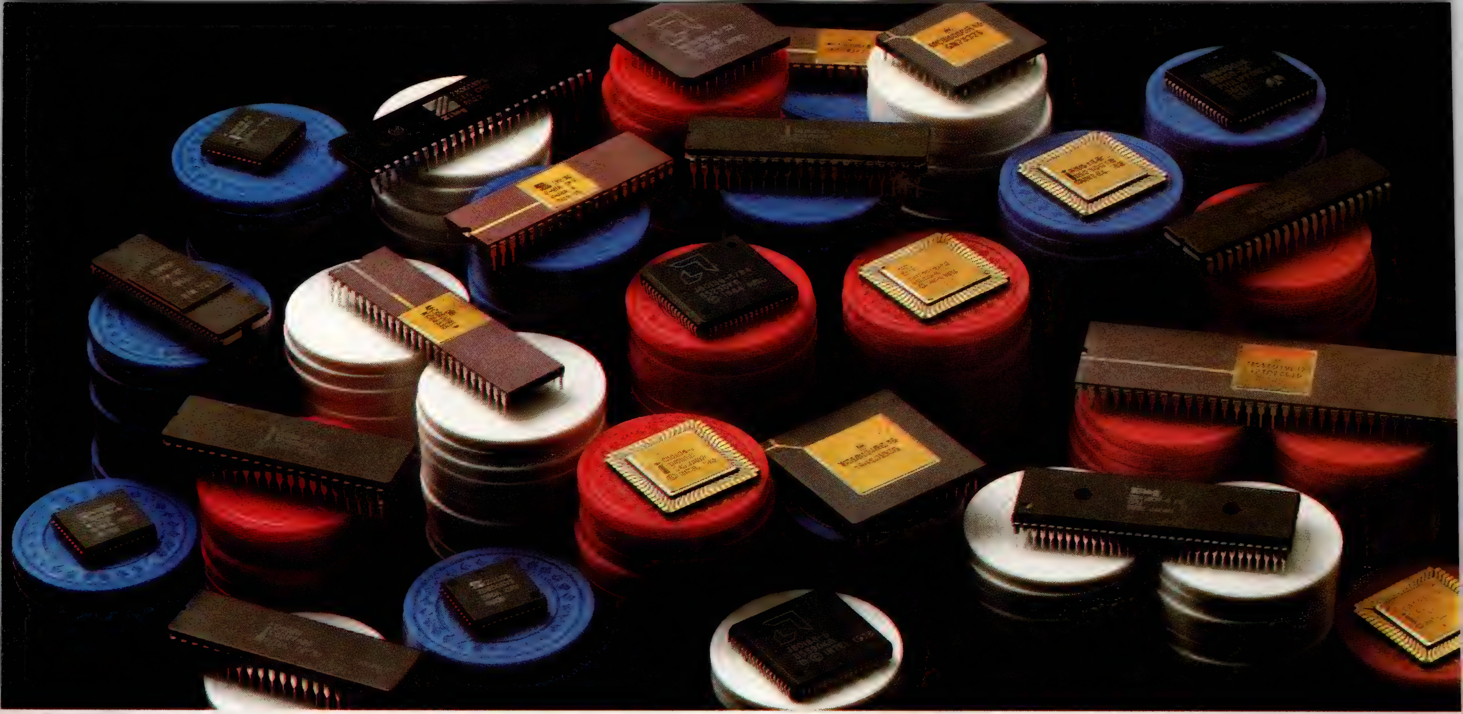
The IEEE-488 bus (or GPIB) provides a quick, convenient method of connecting instruments as an ATE system, but generating the software to control these instruments has always been a time-consuming task. Now, however, you can obtain personal-computer-based CASE (computer-aided software engineering) tools that speed up the process of developing software for IEEE-488 systems. Most of these tools allow you to program in conventional languages; one eliminates the need for a conventional programming language. Further, some of these tools help you generate good documentation for your programs. IEEE-488 program-generation tools are available for both IBM PC-family and Apple Macintosh computers (see **box,** "Macintosh icons ease IEEE-488 programming").

The main reason why IEEE-488 software has often proved difficult to write is that it required the software developer to know in detail how particular instruments operate on the IEEE-488 bus. For example, the programmer had to know the instruments' programming codes, data formats, status-code responses, and internal timing. Despite attempts to standardize some of these parameters—notably in the US Air Force's MATE (modular automated test equipment) program and, more recently, in the new IEEE standard (IEEE-488.2) produced by the organization's P981 committee—currently available instruments vary widely in the way you control them via their IEEE-488 interfaces.

To overcome this problem, software vendors have devised a generation of PC-based software-development tools that include libraries of instrument drivers for popular IEEE-488 instruments. These drivers provide you with an on-screen description of an instrument's functions. After you select the functions you require, the driver automatically assembles both the programming string for the corresponding instrument and the program statement required to transmit the string over the IEEE-488 bus. You can execute this program statement immediately to test whether the instrument responds correctly, and then incorporate the statement in your run-time program.

If you want to use an instrument for which the library doesn't provide a driver, however, you'll either have to write it yourself, or coax the instrument manufacturer, software supplier, or a third party to write it for you. Clearly, the instrument manufacturer has the most intimate knowledge of the instrument, and the software supplier understands best how to generate instrument library files. Ideally, therefore, a new instrument driver would be a cooperative effort between the instrument manufacturer and the software supplier.

If you're left to write the driver yourself, you're back to square one. You'll need a detailed understanding of the instrument, the library-generation tools, and the operation of the IEEE-488 bus in order to do the job competently. Fortunately, most



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companies would only need to hire one programmer with this detailed knowledge to serve the instrument-driver needs of all their application programmers.

Check library support

Before you buy IEEE-488 program-generation software, check carefully to find out how much support you'll get from the supplier in extending the instrument library to cope with your current and future IEEE-488 instrumentation needs. Remember, that it's in the software supplier's best interest—as well as your own—to extend the instrument library. Therefore, as long as the instrument you want to use isn't one of a kind, you might have success in persuading the software supplier to generate the driver for you at no charge. If possible, you should lend the supplier the instrument so that the driver can be fully tested.

User groups, such as the one run by Summation Inc, are another useful source of instrument drivers. However, irrespective of where you obtain instrument drivers, it's important to ensure that they're capable of exercising all of an instrument's functions—not simply a subset of the instrument's functions that satisfies some other user's requirement.

Well-documented code

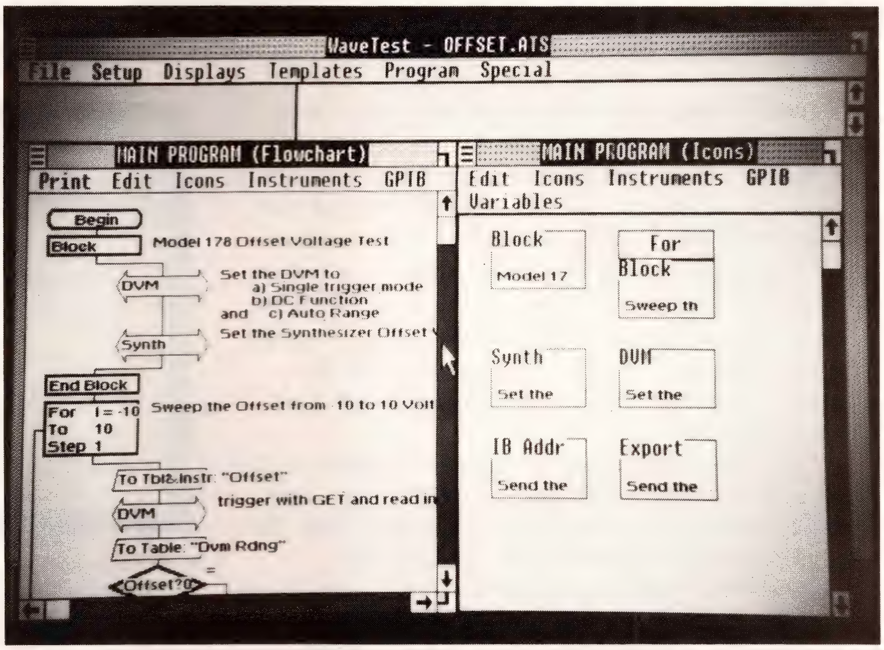
IEEE-488 program generators don't just overcome the problem of writing instrument-driving software: They also help you generate well-documented, error-free program code. Because they let you allocate a meaningful name to each IEEE-488 bus address, you can select devices by name rather than by number. For the standard bus functions (for example, device triggering, device initialization, and serial polling), which are selectable from on-screen menus, the program generator only requires you to define a set of device names; it can then construct a syntactically correct program statement to execute the function. When you list programs on a printer, this symbolic addressing automatically appears on the printout, together with a comment field that explains the function of the program statement.

A window on your problems

Most IEEE-488 program generators produce Basic source code, so when you use these packages, it's usually an advantage to have some experience with the Basic programming language. To run Summation's Testwindows, for instance, you need to be familiar with the TestBasic language. Operating within a Microsoft Windows environment (the latest release, Testwindows 3.0, runs under Windows 2.0 or Windows/386 and is upwardly compatible with the OS/2 Presentation Manager Interface) Testwindows subdivides the task of programming IEEE-488 systems into a number of individual tasks, each supported by its own window and extensive mouse-driven pull-down menus. Because Testwindows operates under Microsoft Windows, you can have several active windows on the screen at the same time.

One of the windows gives you direct access to the MS-DOS operating system, allowing you to call up any MS-DOS-compatible software package from within Testwindows. It's therefore easy to integrate data-analysis and -display software packages—such as Write, Lotus 1-2-3, Excel, and Paint—in Testwindows.

Although you'll have to generate much of your application program in TestBasic, each time you need to control external instrumentation via the IEEE-488 bus, you can call on the services of an IEEE-488 window that automatically generates the required code in the form of documented TestBasic statements. The IEEE-488 window exists either as an uncommitted IEEE-488 window or as a custom device window.



The flowchart- or module-programming techniques *provided by Wavetek's Wavetest package let you use 19 standard program-module icons to program IEEE-488 systems. Where necessary, however, you can also incorporate segments of Basic code in your program.*

The uncommitted window provides simple menu selection and parameterization of TestBasic's normal IEEE-488-bus commands. The custom device window, however, provides on-screen lists that detail an instrument's capabilities (for example, a DMM's functions, ranges,

read rates, and filter selections). You select the required instrument functions from these lists, and Testwindows automatically generates the appropriate IEEE-488 command strings and TestBasic program statements.

To assist you in debugging your application software, Testwindows devotes part of the IEEE-488 window to displaying the data transfers that take place over the IEEE-488 bus. The display indicates the direction of the transfer—system controller to instrument or instrument to system controller—and the state of the IEEE-488 bus's service-request line (SRQ). In addition to selecting an instrument's functions from within the custom device window, you can also use the learn mode featured in some IEEE-488 devices. In learn mode, you set up the instrument from its own front panel, and then command it to send its current state over the bus. The IEEE-488 window can translate this state information and highlight the appropriate functions on the custom device window's function lists.

Summation's instrument library currently contains more than 100 instrument drivers that the company's user group distributes free of charge. Most of these drivers were written by Summation. Those that users write are vetted by Summation before being distributed.

Create your own drivers

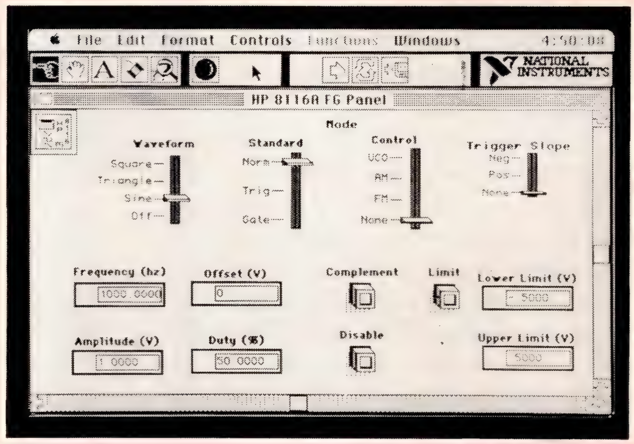
To help you generate custom device windows, Testwindows includes a special IEEE-488 window editor. Pull-down menus within the editor allow you to create lists of instrument functions and to assign the appropriate IEEE-488 programming codes to each function. You can also set up procedures that perform other IEEE-488 opera-

Macintosh icons ease IEEE-488 programming

You don't need to be competent in a formal text-based programming language to use National Instruments' Labview IEEE-488 program-generation package, which runs on the Apple Macintosh and sells for $1995. In fact, if you're already familiar with the Macintosh's icon-based operating system, you'll find Labview very easy to use. In Labview, icons replace the conventional text-based program statements, so Labview is a programming language in its own right; it compiles directly into executable code.

Program construction in Labview depends on the concept of virtual instruments, instruments that exist as software models within the computer. Because of its on-screen graphics capabilities, Labview lets you provide these virtual instruments with front-panel controls and data displays very similar to those you'd find on a physical instrument: slider controls, rotary knobs, pushbuttons, thumbwheel switches, analog meters, and digital readouts, for example. Note, however, that virtual instruments don't always mimic real instrumentation; they can just as easily implement computation functions for analyzing data.

Labview includes virtual-instrument libraries for data analysis and display, as well as a library of IEEE-488 instrument drivers. The data-analysis library contains waveform-analysis, statistical-analysis, matrix- and vector-arithmetic, signal-processing, curve-fitting, and database-management functions. The instrument-driver library includes more than 90 commonly used IEEE-488 instruments. If the instrument you want to use isn't in the library, as with the company's Labwindows



Using the sophisticated graphics icons provided by Labview, you can generate virtual-instrument front panels with controls that mimic a real instrument's controls. Each front panel also has an associated block diagram in which you can simulate the instrument's functions, so you can evaluate your program without connecting any actual instrumentation to the Macintosh.

drivers, you can ask National Instruments to write a driver for you at no charge.

Labview doesn't only control instrumentation connected via an IEEE-488 bus. The package also supports instrumentation connected via an RS-232C or RS-422 serial bus, as well as IBM PC/AT-compatible I/O cards that plug into the MacBus I/O expansion box.

Because the company recognizes that Labview's icon programming on its own won't solve everyone's application problems, the latest release (version 1.2) of Labview lets you integrate in your programs segments of code written in Think Technologies' LightspeedC.

tions, such as reading data from an instrument or evaluating its serial-poll status-byte responses.

Besides using the program's simple fill-in-the-blank procedure for creating the custom device window, you can add a section of code to each item or group of items in the custom device window's function lists. Written in the window editor's custom-function language, these sections of code allow you to add intelligence to function selection. For example, you could cross-couple the voltage and current-limit settings for a programmable power supply to alert the programmer to excursions beyond the supply's power limit. You could also translate binary status information from an IEEE-488 bus device into the corresponding settings in the custom device window, or you could write bus-error-handling routines.

The Testwindows package costs $2950 and includes Microsoft Windows 2.0 and a selection of Microsoft-supplied windows. To run it, you need an IBM PC/AT or compatible computer with 640k bytes of memory, an EGA card, a suitable color monitor, and either a National Instruments PCII or PCIIA card or an IBM GPIB interface card. To accommodate large application programs, Testwindows also supports memory-expansion systems such as the Intel Above-Board or AST Rampage board. However, even with a standard PC/AT you can lock frequently used subroutines into the PC's RAM, leaving others to be accessed from disk.

Wavetest, a software package launched by Wavetek Inc in October 1987, is similar to Summation's Testwindows. It runs in a mouse-driven Microsoft Windows environment and uses custom device windows that allow you to control IEEE-488 instruments. Wavetest is significantly different from Testwindows, however, in that it doesn't require you to generate syntactically correct Basic statements in order to generate the bulk of your program: Hence, Wavetek claims, you get no syntax errors.

Program with flowcharts

Instead of writing the program with Basic statements, you can opt to write it by using either flowchart- or module-programming methods. Wavetest's flowchart-programming window allows you to build an on-screen program flowchart by using 19 flowchart modules that you can parameterize as necessary. These flowchart modules include program-flow structures (for example, DO-WHILE loops, FOR-NEXT loops, subprogram calls, and IF statements); modules to control the IEEE-488 bus; and I/O control

IEEE-488 add-ons enhance analysis tools

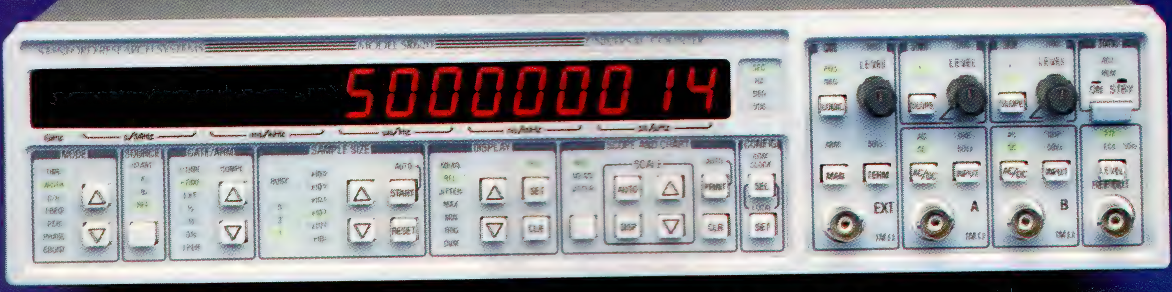
Instead of using a dedicated program-generation tool, you can obtain add-on packages that allow industry-standard data-analysis software to gather data from IEEE-488 systems. For example, by integrating Lotus Measure in Lotus 1-2-3, you can transfer data directly between an IEEE-488 bus system and a Lotus 1-2-3 worksheet. However, Lotus Measure doesn't provide an instrument-driver library, so you'll have to generate your own drivers by building worksheet macros that invoke the required IEEE-488-bus command sequences.

Supplied on a floppy disk, Lotus Measure's IEEE-488 module contains additional routines that you can add to Lotus 1-2-3's normal device-driver file. The module provides two sets of IEEE-488 routines: one for use with National Instruments' IEEE-488 interface cards; and one for use with a Hewlett-Packard HP-IB interface card. The IEEE-488 module provides Lotus 1-2-3 with 22 additional bus-oriented macro commands that you can invoke through Lotus 1-2-3's normal menu-access procedures. A similar package is available for use with Lotus Symphony. Both packages sell for $495.

In the coming months, you can also expect to see a new data-acquisition and -analysis package from Asyst Software Technologies Inc. At present, the company's Asystant range of data-acquisition, analysis, and graphics software supports only PC-compatible A/D- and D/A-converter boards. In the near future, however, the company plans to release a $695 software package, Asystant-GPIB, that incorporates menu-driven IEEE-488 functions, so it can control and acquire data from IEEE-488 systems rather than from data-acquisition cards. Asystant-GPIB runs on the whole family of IBM PCs and can accommodate a range of IEEE-488 interface cards.

Upon entering Asystant-GPIB, you can allocate a symbolic name, a primary and secondary bus address, and a bus timeout to each instrument on the IEEE-488 bus. After that, you have the choice of entering either an interactive mode or a program-generation mode. In the interactive mode, you're presented with a menu of IEEE-488 operations that lets you directly control instruments on the bus. By executing these operations, you can check such things as programming strings and instrument responses. The program mode allows you to incorporate these bus operations in your application program. Whichever mode you're using, you can still invoke Asystant's numerical- and statistical-analysis functions.

Time interval measurement. $3850.



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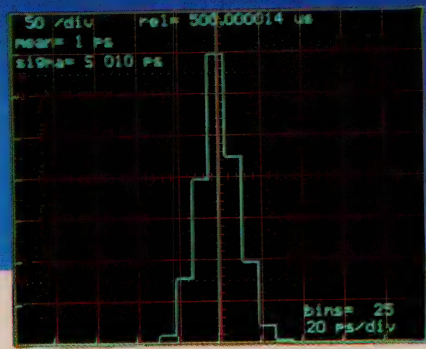

The SR620 provides graphic display of histograms and strip charts on any X-Y oscilloscope. With Autoscale and Zoom, graphics can be easily scaled. Attach a dot matrix printer or an HP-GL plotter and obtain hardcopy of any graph.

Finally, high resolution time interval measurement at an affordable price. The SR620 Universal Time Interval Counter offers 4 ps single-shot LSD on time intervals, and 11 digits of frequency resolution in one second. With powerful arming, gating, and triggering modes, the SR620 can measure time interval, frequency, period, pulse width, and phase, as well as rise and fall times.

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With both RS-232 and GPIB interfaces standard, the SR620 is also ideal for ATE applications.

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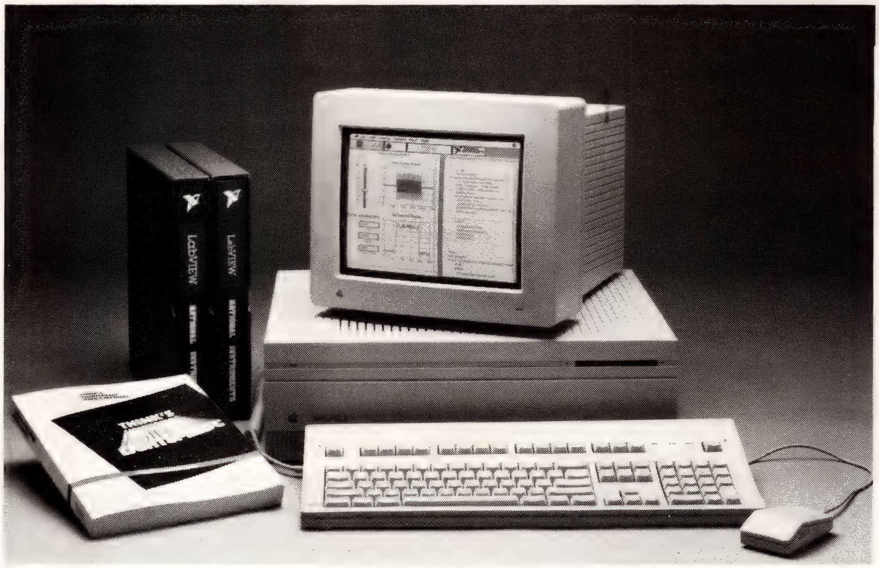
modules to control file generation and to direct output to computer peripherals.

Other modules allow you to incorporate delays in the program, generate test-report documentation, set up run-time error handlers, and activate an operator window so that an operator can interact with the program during its execution. To program an instrument, you simply go to the instrument menu, select its custom device window, interact with the instrument until you're sure that it responds correctly, and then incorporate the operation in your flowchart.

The program also offers the Basic module, which lets you use TransEra Corp's (Provo, UT) TBasic programming language to write those parts of your program that can't be created from the standard flowchart modules. The standard flowchart modules let you create the program structure and I/O-control segments of your program. You'll have to resort to using TBasic to generate code that analyzes the captured data (for example, to compute the standard deviation of measurement values for entry into a test report).

In addition to using individual



The Labview software package *from National Instruments turns a Macintosh computer into a powerful IEEE-488 controller that you can program entirely with icons. The latest release of Labview (version 1.2) also allows you to integrate code written in Think Technologies' LightspeedC in your programs.*

modules, you can also create block modules that comprise the other modules. You can also nest block modules within other block modules. Therefore, a single block-module icon can represent a large section of code, which you can examine by opening the icon.

Wavetest's alternative to flowchart programming is module programming. To construct a program in this window, you simply arrange the icons that represent the modules in the order in which you want them to execute, from left to right and top to bottom on the screen. Reordering the icons on the screen rearranges the program flow. You can have the flowchart window and module window on the screen simultaneously. If you make changes in one window, the other window is automatically updated to reflect the revised program.

One advantage of using the flowchart programming technique is that it forces you to write structured programs, overcoming a common criticism of Basic—namely, that it doesn't encourage structured programming. In addition, by downloading the flowchart and listings of each module to a printer, you can generate program documentation. To make the documentation easier to understand, listings for the standard module set include English-language descriptions of the module's function rather than containing only the Basic source code.

In addition to the normal debugging aids found in most of these programming packages—for example, breakpoint set, program-step, and trace-variable functions—Wavetest also includes a built-in IEEE-488 bus analyzer. This analyzer captures all IEEE-488 bus traffic, displaying both the talk and listen addresses associated with each message transfer and the transferred device-dependent data.

Although Wavetek recommends that you run Wavetest on an IBM PC/AT or compatible computer with 640k bytes of RAM, an EGA card and monitor, and a Microsoft Windows-compatible mouse, you can run the program on a monochrome IBM PC/XT. The $3990 price includes Microsoft Windows, an IEEE-488 interface card for the PC, and an instrument library that currently contains drivers for over 50 popular IEEE-488 instruments.

National Instruments' latest software package, Labwindows, costs only $495, but boasts IEEE-488 program-generation facilities similar to those provided in Summation's Testwindows package. Labwindows also runs on a wider range of IBM PCs—from a 512k-byte, IBM PC with at least two floppy-disk drives (however, the company recommends 640k bytes of RAM and a hard-disk drive) to an IBM PC/AT or PS/2—and allows you to

program in Microsoft QuickBasic and Microsoft C.

Part of the reason for the lower price is that Labwindows doesn't operate under Microsoft Windows, so the vendor doesn't have to pass along the cost of Windows to the consumer. Although you'll save money, however, you'll have to put up with a less-sophisticated programmer interface that uses simpler text-based screens, and you won't be able to work in multiple screen windows at the same time.

Labwindows provides three basic windows in which you can generate, edit, and execute application programs: a program-buffer window with a full-screen editor, a standard I/O screen that allows user-input and data display during program execution, and an interactive window that allows you to selectively execute or debug sections of program. As with Testwindows, Labwindows offers pull-down menus, so you can access the functions and libraries relevant to the window that you're working in, and you operate the windows and menus with the PC's keyboard or a mouse.

Labwindows was released at the end of February this year, and at that time its instrument library contained only six instrument drivers. Michael Santori, National Instruments' product marketing manager for Labwindows, points out that these drivers are included in the package largely to illustrate the type of drivers that users could write themselves. However, Santori says, the company will continue to develop and supply instrument drivers free of charge, at least until the library is large enough to satisfy the majority of users.

If you undertake the task of writing an instrument driver yourself, you'll have help: Labwindows provides libraries of IEEE-488 bus control, and data-formatting routines. As with the instrument library itself, you apply these libraries by using on-screen function panels selected from pull-down menus. The IEEE-488 bus-control library contains more than 30 routines (the ones normally supplied in National Instruments' PC-DOS GPIB handler) which provide both high- and low-level control over the IEEE-488 bus. Labwindows also provides menu assistance in building the graphics screens for the instrument's on-screen function panels.

In addition to the GPIB and data-formatting libraries, Labwindows also comes with libraries of routines for presentation graphics and basic data analysis (for example, array arithmetic, complex arithmetic, and statistics). For an additional $895, you can buy a library of advanced data-analysis routines.

All Labwindows' library routines are accessible from within the program's interactive environment via function panels. Once you've generated a complete program, you can run it through the Labwindows compiler or save it as QuickBasic or C source code, which you can run through third-party compilers if necessary.

Another software package, the Guru-II from Tektronix, is primarily intended to support waveform acquisition and analysis on the company's digitizers and digital oscilloscopes. Unlike the other packages discussed so far, this package doesn't include an editor that allows you to generate on-screen, menu-driven instrument drivers for IEEE-488 instrumentation from other companies. What it does provide is a set of Basic subroutines that execute standard IEEE-488 bus functions (for example: send a bus message, read a device, conduct a serial poll) and a test-program generator that allows you to create tests and modify test procedures. However, when creating these test procedures, you'll have to enter the required instrument-programming strings manually. The Guru-II software package runs on the IBM PC, PC/XT, or PC/AT. It's available with or without an IEEE-488 interface card and interface cable; it costs $850 with the card and cable and $450 without.

Back to Basic

All the IEEE-488 program-generation packages discussed so far allow you to program directly in Basic if you want to. At times, the ability to write directly in Basic—coupled with a thorough understanding of IEEE-488 bus protocols and instrument operation on the bus—may prove invaluable.

For example, if you want a high-

For more information . . .

For more information on the IEEE-488 program-generation tools described in this article, contact the following manufacturers directly, circle the appropriate numbers on the Information Retrieval Service card, or use EDN's Express Request service.

Asyst Software Technologies Inc
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Rochester, NY 14623
(716) 272-0070
Circle No 700

Lotus Development Corp
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Cambridge, MA 02142
(617) 577-8500
Circle No 701

National Instruments Corp
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Austin, TX 78727
(512) 250-9119
Circle No 702

Summation Inc
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Kirkland, WA 98034
(206) 823-8688
Circle No 703

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San Diego, CA 92123
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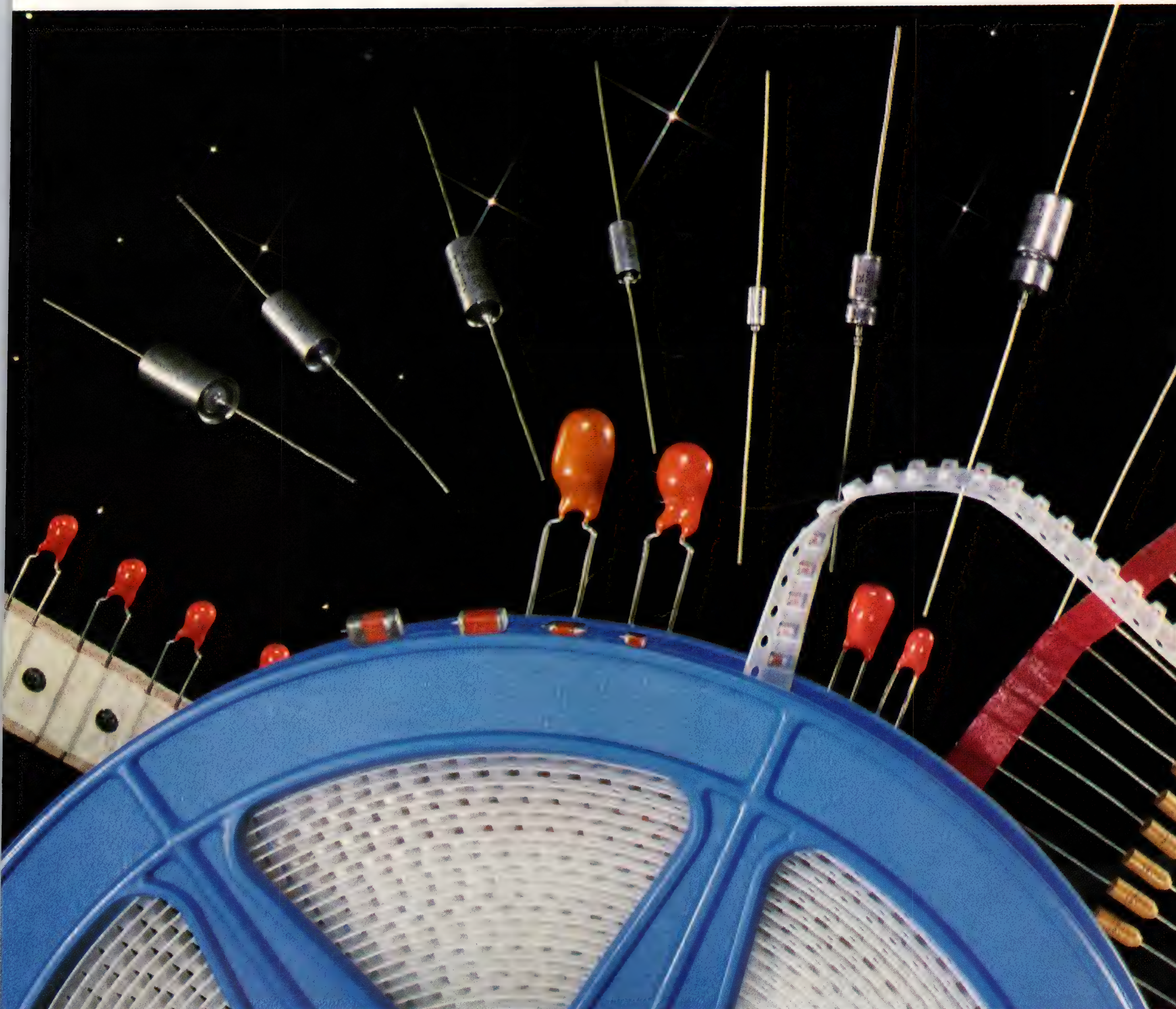

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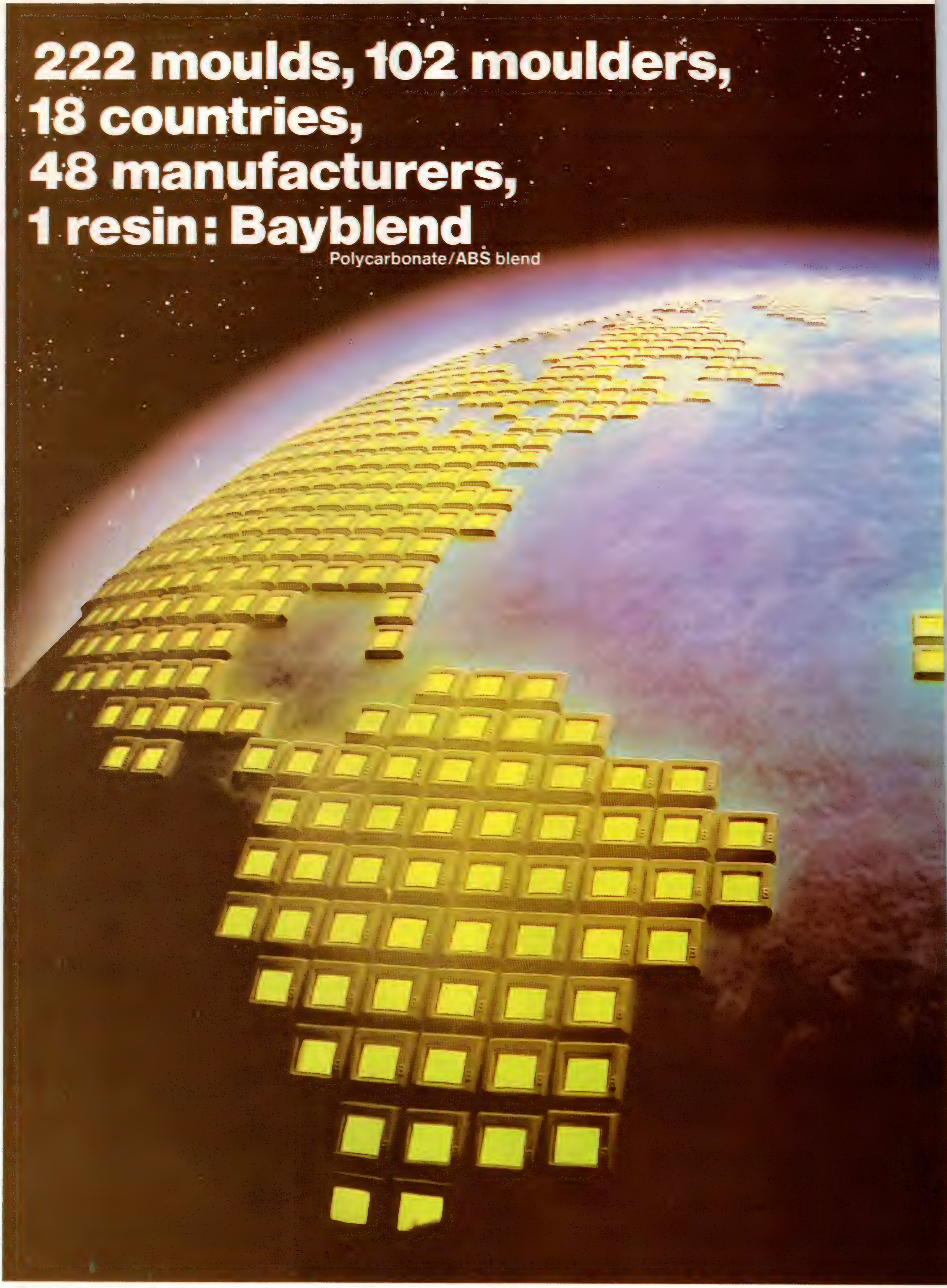
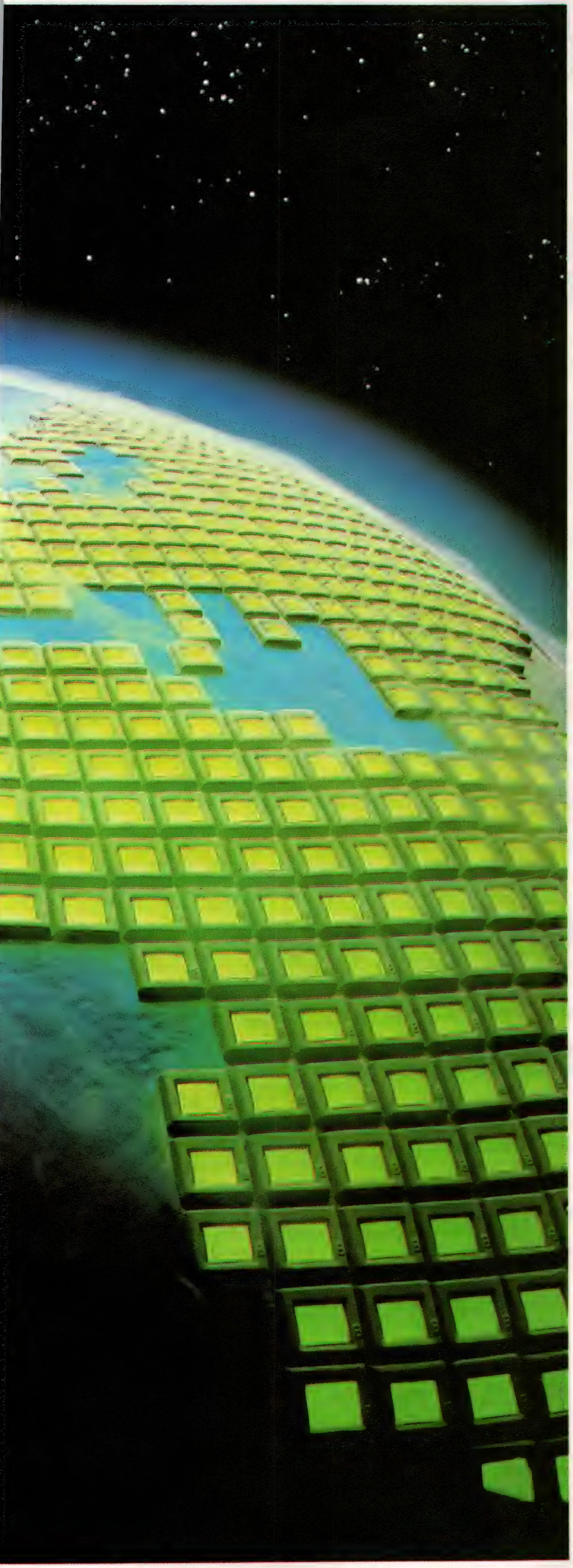
speed instrument to operate continuously at its maximum read rate and to send measurement data over the IEEE-488 bus, you'll probably need to set up a fast I/O channel. This task involves leaving the instrument addressed to talk and opening up a DMA channel to transfer the instrument's output data directly into the PC's memory. Because you can't afford the overhead of sending the instrument an Untalk (UNT) command followed by a group-execute-trigger (GET) command, you'll have to operate the instrument in an automatic-retriggering mode, so that it retriggers itself as soon as it has generated (but not sent out) new measurement data. When you're operating the instrument in this maximum read-rate mode, you'll have to ensure that the instrument can send its data over the IEEE-488 bus during the time it takes to generate new measurement data—for example, during the conversion period of an A/D converter or the gating period of a counter.

In addition, to ensure that the PC's IEEE-488 interface gets instant DMA access to the PC's data bus, you may have to halt the PC's processor while the fast I/O transfers take place, and you'll have to implement a mechanism to return control to the Basic program when the DMA buffer is full. Further, don't be fooled into thinking that just because your IEEE-488 interface card specs a data-transfer rate of 1M byte/sec, data transfers will take place at that rate. The IEEE-488 handshake is a two-way affair involving both the interface card and the addressed instruments. Typical instruments will slow the actual transfer rate to a few hundred thousand bytes per second. **EDN**

Article Interest Quotient
(Circle One)
High 515 Medium 516 Low 517



* Tektronix is a registered trademark of Tektronix, Inc.



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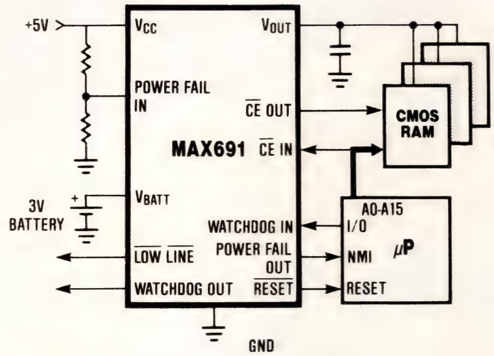

Power-On Reset.

The MAX690 and 691 have a precise 4.65V threshold detector and 50ms timer that generates an accurate reset signal for any power-on, brown-out or momentary interrupt condition.

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A watchdog circuit built into each MAX690/691 constantly monitors all μP activity. It detects both hardware and software malfunctions and automatically issues a reset command to the μP—effectively eliminating 'lock-up' conditions.

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Largest-ever Electro adds software to its showcase of electronics technology

Tarlton Fleming, *Associate Editor*

The theme for the Electro/88 conference, scheduled for May 10 through 12 at Boston's Bayside Exposition Center and World Trade Center, centers on the technology bridge between hardware and software. To underscore this theme and emphasize the growing importance of software in the development of electronic products, the show is featuring a "spotlight on software." There will be 35 software-oriented technical sessions, and a record number of software companies will be exhibiting. As usual, Electro's other exhibits, technical presentations, and general-interest events should draw a large audience from the electronics community. The show's sponsors, the IEEE and the Electronics Representatives Association, expect attendance to be about 50,000.

Electro and Mini/Micro Northeast were separate conferences last year, but Electro/88 will combine the two and offer 1300 exhibits and 54 technical sessions. Exhibition hours are 9:30 AM to 5:00 PM; technical-session hours are 9:00 AM to 5:30 PM. Before April 21, the registration fee is \$5; after that, admission is \$20 (\$10 for IEEE and ERA members).

IEEE awards medals

Two IEEE awards ceremonies will precede the official activities of Electro/88. In the Sheraton-Boston Hotel at a noon luncheon on Monday, May 9, the IEEE Engineering Leadership Recognition and the Corporate Innovation Recognition awards will take place. At 6:00 PM, the hotel will host the IEEE's annual medals presentation, which will include the awarding of three newly established medals. These activities are open to members only.

Several other special events are scheduled during Electro/88. On Tuesday May 10, Lester C Thurow will deliver the keynote address, "building a world-class US economy." Thurow is an economist, a professor of management and economics at MIT, and the dean of MIT's Sloan School of Management. The keynote breakfast will be held at Anthony's Pier 4 restaurant at 8:00 AM.

A marketing-management conference, "how to pick the right sales force and make it work," will offer insights into choosing the proper sales channels, measuring results, and motivating salespeople to generate forecasts. The 2-hour conference, based on case histories and featuring audience participation, will begin at 10:00 AM on Wednesday, May 11, in the World Trade Center. Marketing consultants John Haskell and Jerry Frank will run the conference.

At noon on Wednesday, Michael Tinkham will speak on "superconductivity, past, present, and future" at Anthony's Pier 4 restaurant. Tinkham is a professor of physics at Harvard University and an experimenter in superconductivity. The talk is open by invitation only to IEEE life members (those for whom their age plus years in the IEEE adds up to at least 100). Admission is \$2.50 for members and spouses, and \$15 for guests.

Tutorial sessions are free

Last year at Electro, you had a choice of five tutorial sessions that cost between \$280 and \$410 for non-IEEE members. This year's 12 tutorials, mixed into the schedule of professional-program sessions, are free. These tutorials offer you an overview of a subject that may not be within your field. For convenience, many are followed by one or more sessions on related topics. Some topics are marketing, technical documentation, electronic publishing, software development, GaAs devices, testing, CAE, CIM, and mechanical CAD/CAM.

Highlights of the technical sessions include "simulation of analog and mixed-mode circuits," "floating-point coprocessors for advanced personal microprocessors," "RISC technology enters the mainstream," "high-temperature superconduc-

tors," "robots in the real world," "development tools for digital-signal processors," and "recent advances in 'application-specific' PLDs."

In addition to the applications-oriented technical presentations, the professional-program sessions cover an assortment of nontechnical engineering issues. These include "engineering education—responding to real-world demands," "Strategic Defense Initiative: assessment of progress and prospects," "supporting the ethical engineer," and "social implications of artificial intelligence."

The exhibits at Electro/88 will cover active and passive compo-

PROFESSIONAL-PROGRAM SESSIONS

WORLD TRADE CENTER

			TUESDAY, MAY 10
COMMERCIAL COMPLEX 1	**COMMERCIAL COMPLEX 2**	**COMMERCIAL COMPLEX 3**	**TEACHERS UNION E**
9:00 AM TO 11:30 AM **TUTORIAL 1** MARKETING, THE KEY TO PRODUCT SUCCESS	9:00 AM TO 11:30 AM **TUTORIAL 2** ELECTRICAL CAD	9:00 AM TO 11:30 AM **TUTORIAL 3** TECHNICAL DOCUMENTATION FOR ELECTRONIC PRODUCTS	9:00 AM TO 11:00 AM **SESSION 4** MODERN METEOR-BURST COMMUNICATIONS
12:30 PM TO 2:30 PM **SESSION 7** SALES AND MARKETING: CLOSING THE SOFTWARE GAP	12:30 PM TO 2:30 PM **SESSION 8** MODELING STRATEGIES FOR ASIC DESIGN	12:30 PM TO 2:30 PM **TUTORIAL 9** COMPUTER-AIDED ACQUISITION AND LOGISTIC SUPPORT (CALS)	12:30 PM TO 2:30 PM **SESSION 10** HIGH-TEMPERATURE SUPERCONDUCTORS
3:30 PM TO 5:30 PM **SESSION 13** EXPORTING SOFTWARE TO JAPAN—FACT OR FANTASIES	3:30 PM TO 5:30 PM **SESSION 14** DESIGN TOOLS FOR NEW PROGRAMMABLE SILICON DEVICES: DOES ONE SIZE FIT ALL?	3:30 PM TO 5:30 PM **SESSION 15** CORPORATE ELECTRONIC PUBLISHING	3:30 PM TO 5:30 PM **SESSION 16** ROBOTS IN THE REAL WORLD
			WEDNESDAY, MAY 11
9:00 AM TO 11:30 AM **TUTORIAL 19** ENGINEERING TO MEET CUSTOMER NEEDS	9:00 AM TO 11:30 AM **TUTORIAL 20** SOFTWARE DEVELOPMENT FOR REAL-TIME EMBEDDED SYSTEMS	9:00 AM TO 11:30 AM **TUTORIAL 21** DESIGN FOR TESTABILITY	9:00 AM TO 11:30 AM **TUTORIAL 22** COMPUTER INTEGRATED MANUFACTURING AND BUSINESS DECISIONS
12:30 PM TO 2:30 PM **SESSION 25** SYSTEM SOLUTIONS FOR INCREASING SALES AND MARKETING PRODUCTIVITY	12:30 PM TO 2:30 PM **SESSION 26** CASE TOOLS IMPROVE MANAGEMENT OF THE SOFTWARE CYCLE: INTRODUCTION, USAGE, HISTORIES, FUTURE TRENDS	12:30 PM TO 2:30 PM **SESSION 27** SUCCESSFUL SYSTEM-DESIGN TECHNIQUES USING ASICs	12:30 PM TO 2:30 PM **SESSION 28** CLEAN-ROOM AUTOMATION FROM CIM TO ROBOTS
3:30 PM TO 5:30 PM **SESSION 31** SOFTWARE DESIGN TECHNIQUES FOR INNOVATIVE PLD ARCHITECTURE	3:30 PM TO 5:30 PM **SESSION 32** COMPUTER-AIDED SOFTWARE ENGINEERING (CASE)	3:30 PM TO 5:30 PM **SESSION 33** CHARACTERIZATION AND TESTING OF ANALOG-TO-DIGITAL CONVERTERS FOR DIGITAL SIGNAL PROCESSING APPLICATIONS	3:30 PM TO 5:30 PM **SESSION 34** MACHINE-VISION APPLICATIONS IN ELECTRONICS MANUFACTURING
			THURSDAY, MAY 12
9:00 AM TO 11:30 AM **TUTORIAL 37** MARKETING YOUR PRODUCT, YOUR DEAL, AND YOUR COMPANY	9:00 AM TO 11:00 AM **SESSION 38** ENGINEERING EDUCATION—RESPONDING TO REAL WORLD DEMANDS	9:00 AM TO 11:00 AM **SESSION 39** STRATEGIC DEFENSE INITIATIVE: ASSESSMENT OF PROGRESS AND PROSPECTS	9:00 AM TO 11:30 AM **TUTORIAL 40** MECHANICAL CAD/CAM
12:30 PM TO 2:30 PM **SESSION 43** SIMULATION OF ANALOG AND MIXED-MODE CIRCUITS	12:30 PM TO 2:30 PM **SESSION 44** THE ROLE OF CONFIGURATION-MANAGEMENT TOOLS IN SOFTWARE DEVELOPMENT ENVIRONMENTS	12:30 PM TO 2:30 PM **SESSION 45** SOFTWARE TOOLS FOR TEST AND MEASUREMENT APPLICATION PROGRAM DEVELOPMENT	12:30 PM TO 2:30 PM **SESSION 46** HIGH-INTEGRATION SOLUTIONS FOR PERSONAL COMPUTER/PERSONAL SYSTEM DESIGN
3:30 PM TO 5:30 PM **SESSION 49** LEAP INTO THE 90s WITH AN ACCELERATED NEW-PRODUCT DEVELOPMENT CYCLE	3:30 PM TO 5:30 PM **SESSION 50** UNIQUE SOFTWARE CONSIDERATIONS FOR MICROCONTROLLERS WHEN LISTING HIGH-LEVEL LANGUAGES	3:30 PM TO 5:30 PM **SESSION 51** TEST PROGRAM GENERATION: EXTRACTING TESTER PROGRAMS FROM SIMULATION	3:30 PM TO 5:30 PM **SESSION 52** INDUSTRIAL REQUIREMENTS FOR REAL-TIME DIGITAL SIGNAL PROCESSING (DSP) APPLICATIONS

nents, microelectronics, computer hardware and software, instrumentation, test equipment, control systems, production equipment, assembly tooling, mechanical/electronic packaging, and power sources. **EDN**

Article Interest Quotient
(Circle One)
High 518 Medium 519 Low 520

BAYSIDE EXPOSITION CENTER

TEACHERS UNION F	TEACHERS UNION G
9:00 AM TO 11:30 AM **TUTORIAL 5** IMPLEMENTING COMPUTER INTEGRATED MANUFACTURING (CIM)	9:00 AM TO 11:30 AM **TUTORIAL 6** INTRODUCTION TO GaAs DEVICES, TESTING AND EVALUATION METHODS
12:30 PM TO 2:30 PM **SESSION 11** INTRODUCING NEW PRODUCTS TO MANUFACTURING THROUGH CIM	12:30 PM TO 2:30 PM **SESSION 12** ADVEDNTURES IN TECHNOLOGICAL INNOVATION: HOW THE MASSACHUSETTS MIRACLE WORKS
3:30 PM TO 5:30 PM **SESSION 17** PROCESS PLANNING AND SIMULATION OF MANUFACTURING OPERATIONS	3:30 PM TO 5:30 PM **SESSION 18** DEVELOPMENT TOOLS FOR DIGITAL SIGNAL PROCESSORS (DSPs)
9:00 AM TO 11:00 AM **SESSION 23** RECENT ADVANCES IN "APPLICATION SPECIFIC" PLDs	9:00 AM TO 11:00 AM **SESSION 24** ENHANCING GLOBAL SECURITY THROUGH INFORMATION SHARING
12:30 PM TO 2:30 PM **SESSION 29** ARTIFICIAL INTELLIGENCE IN MANUFACTURING	12:30 PM TO 2:30 PM **SESSION 30** RISK ASSESSMENT AND RESPONSE
3:30 PM TO 5:30 PM **SESSION 35** PUBLISHING OPPORTUNITIES IN THE IEEE	3:30 PM TO 5:30 PM **SESSION 36** SOCIAL IMPLICATIONS OF ARTIFICIAL INTELLIGENCE
9:00 AM TO 11:00 AM **SESSION 41** COMPUTER BACKPLANE INTERFACE USING HIGH-SPEED LOW-POWER CMOS INTERFACE ICs	9:00 AM TO 11:00 AM **SESSION 42** RISC TECHNOLOGY ENTERS THE MAINSTREAM
12:30 PM TO 2:30 PM **SESSION 47** MECHANICAL CAE IMPACTS ON PRODUCT DEVELOPMENT	12:30 PM TO 2:30 PM **SESSION 48** FLOATING-POINT COPROCESSORS FOR ADVANCED PERSONAL MICROPROCESSORS
3:30 PM TO 5:30 PM **SESSION 53** SUPPORTING THE ETHICAL ENGINEER	3:30 PM TO 5:30 PM **SESSION 54** AN ARCHITECTURAL OVERVIEW OF CACHE CONTROLLERS FOR 32-BIT MICROPROCESSORS

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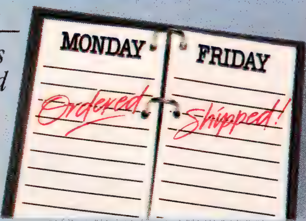

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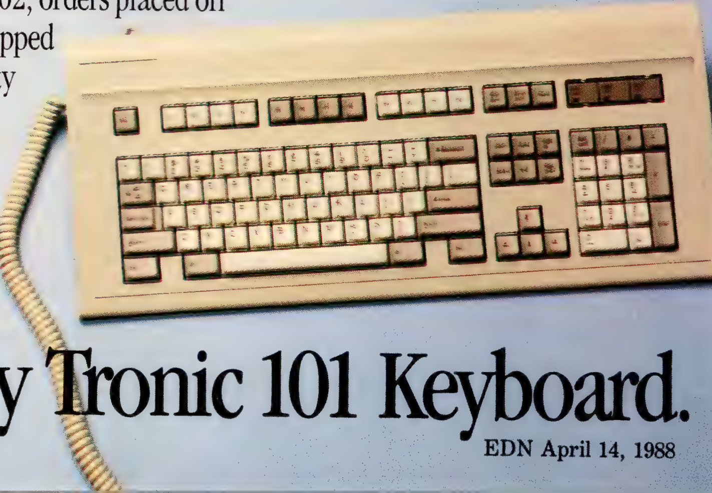
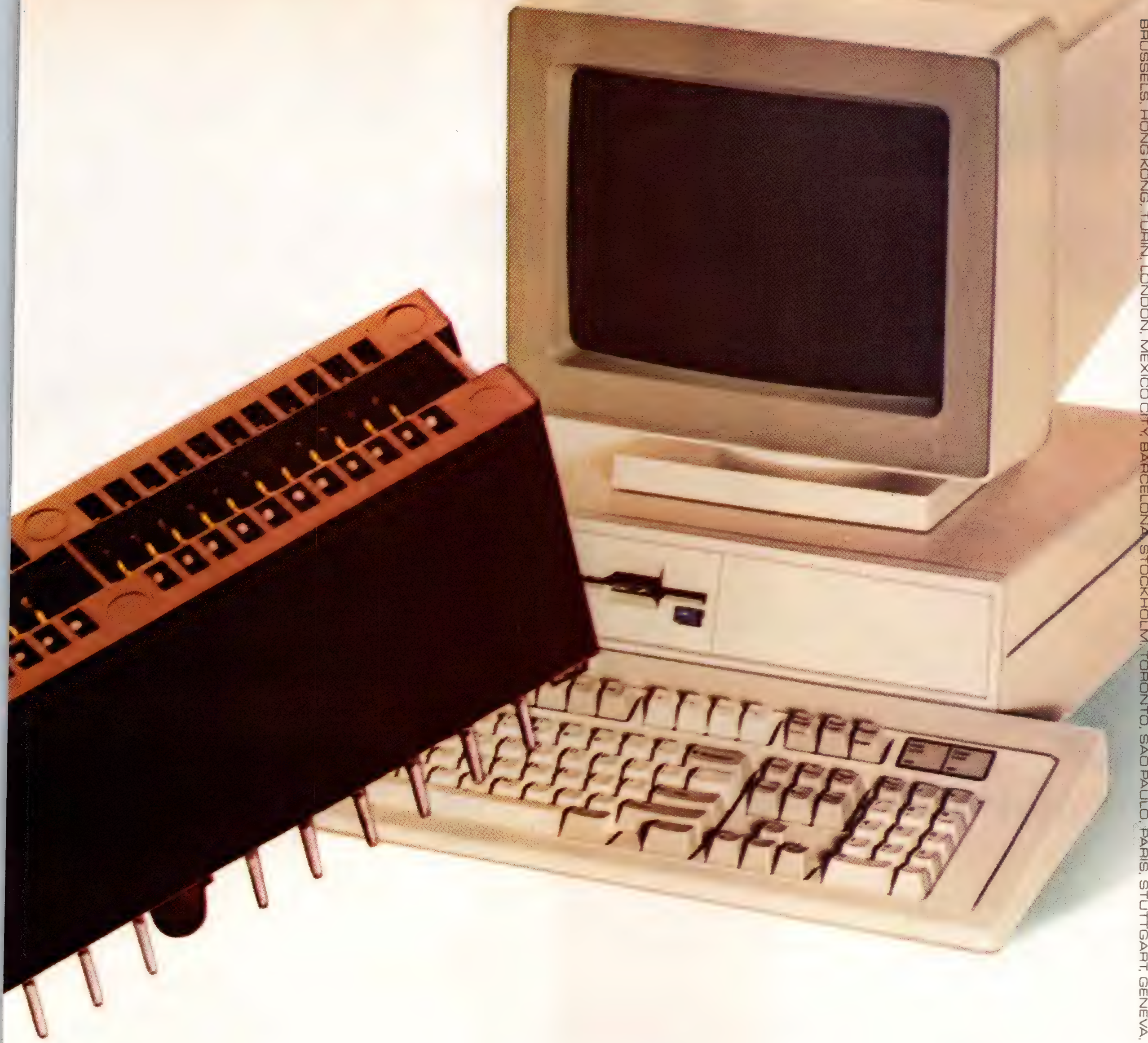


The Key Tronic 101 Keyboard.

CIRCLE NO 54

Burndy introduces the world's most advanced connector for the world's most advanced personal computers.



BURNDY-VALUE BY DESIGN

BRUSSELS, HONG KONG, TURIN, LONDON, MEXICO CITY, BARCELONA, STOCKHOLM, TORONTO, SAO PAULO, PARIS, STUTTGART, GENEVA, SYDNEY, TOKYO, DOMINICAN REPUBLIC, AUSTRALIA, NORWALK, CT AND THROUGHOUT THE U.S.

56421

COMPUTERBUS®—the new card-edge connector that's setting the standard for 2nd generation PCs.

Developed for one of the world's leading computer companies, it represents state-of-the-art technology from start to finish.

New concepts. New materials. New manufacturing techniques have all been incorporated into this remarkable connector.

The results are outstanding.

It's a high density .050 connector. Which means overall space and weight reduction. Shorter signal paths. And greater design flexibility.

It's cost-effective. Engineered that way—with everything designed for quick, easy installation and robotic handling.

It has unmatched reliability over repeated card insertion and withdrawal cycles through severe environmental testing. Built for maximum durability, it incorporates state-of-the-art material and design concepts for dimensional stability and predictable performance over time.

It's a shortcut to compatibility. It's already the standard for 2nd generation PC plug-in feature cards. And it's available now. Today. For test and evaluation. Or in quantity for full production runs. Get the complete story. Call or write: Burndy Corporation, Norwalk, CT 06856. (203) 852-8337.

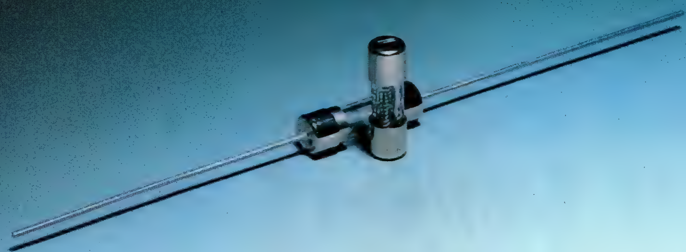
BURNDY

CUSTOMER SATISFACTION COMES FIRST

CIRCLE NO 56

INTRODUCING 2AG FUSES

The world's smallest glass fuse.



Actual size: 0.177″ diameter x 0.58″ long;
Slo-blo® and fast-acting types, rated: ¼ ~ 7A, 250V or less.

Now you can get 3AG reliability and performance in a new economical subminiature size. Our Slo-blo® and fast-acting fuses are perfect for p.c. board and other limited space applications. Order them in bulk, or on tape and reel for high speed automatic insertion. New mating 2AG p.c. board fuse clips are also available.

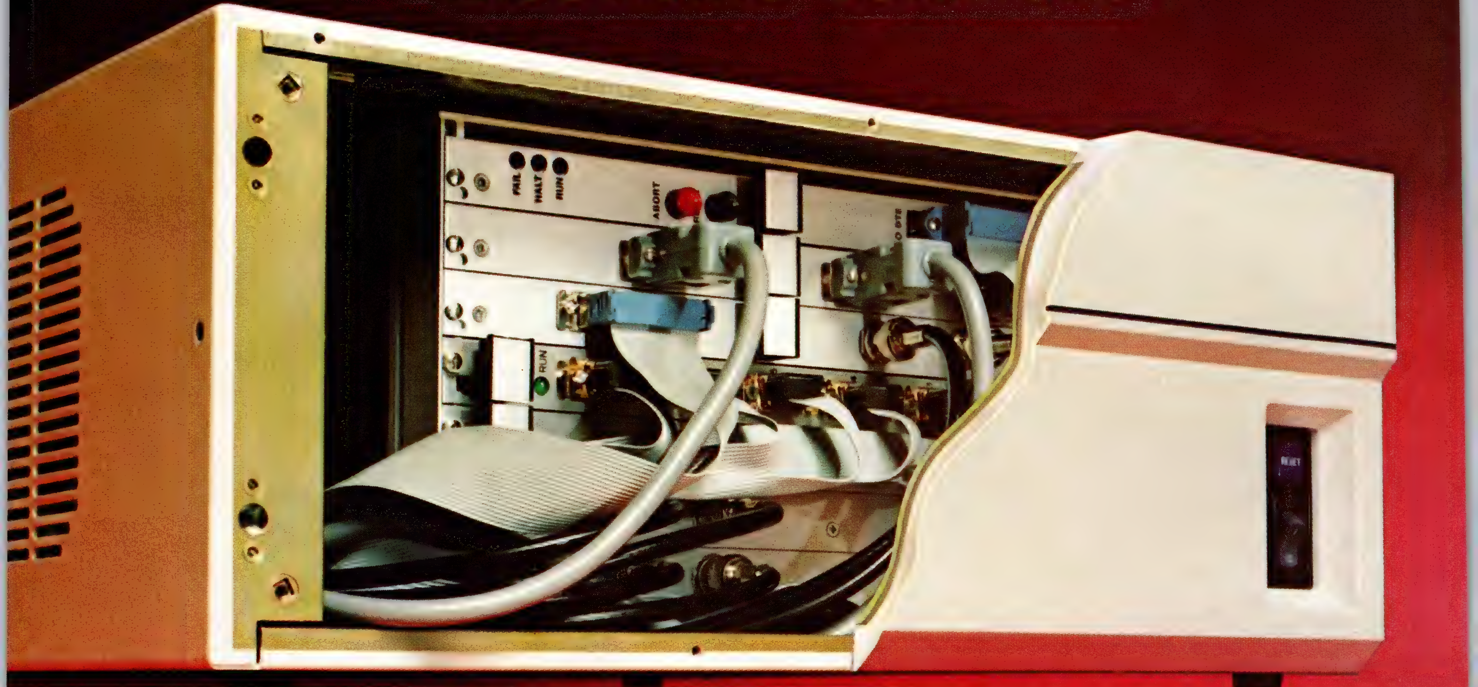
CIRCLE NO 58

Littelfuse® Tracor

800 E. Northwest Highway • Des Plaines, IL 60016
(312) 824-1188

2AG SPACE-MAKERS—SLO-BLO® OR FAST-ACTING PERFORMANCE IN A NEW SUBMINIATURE SIZE

VME + FCC =Electronic Solutions



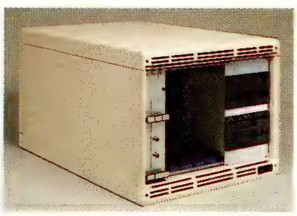
The only VME System Enclosures with EMI/RFI Compliance

With Electronic Solutions VME enclosures you don't have to take any static about FCC compliance. Because your VME system can meet or exceed FCC Class A Part 15 EMI/RFI standards. No other enclosure manufacturer can make that statement.

Here's why: Only Electronic Solutions puts a new face on VME, an outer front panel that—with other design features—keeps your EMI/RFI signals from straying. What's more, it hides those I/O connectors and dangling cables so your system looks a lot cleaner and more attractive.

Electronic Solutions enclosures for VME—and Multibus I/II—come assembled complete with card cage, backplane, power supply, room for peripherals and more. You can get slim enclosures with 3 slots all the way up to multi-system enclosures with 40—count 'em—40 slots. And you buy them ready for your system at a tiny fraction of what it would cost to develop your own packaging.

THREE YEAR 3 LIMITED WARRANTY



GEMINI enclosures to 40 slots.

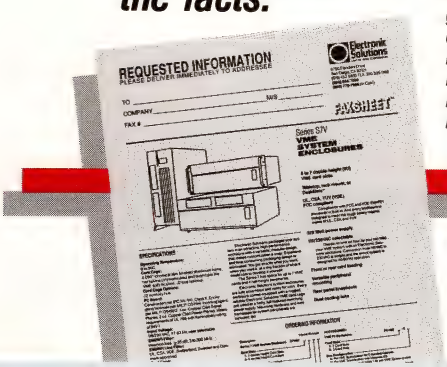
SERIES enclosures to 12 slots.

BAUART GEPRÜFT IEC380 FCC

In addition, there are a few other agencies besides the FCC that can help multiply your system's success. So Electronic Solutions enclosures pass UL, CSA, and TUV/IEC 380 as well.

Call today for complete details. Because no matter what formula you planned to use for system packaging, putting your system in our enclosures is the one that really adds up.

We'll FAX you the facts.



Want the latest data in a hurry? Nothing is faster than Electronic Solutions' new "FAX the FACTS" program. If you have a FAX machine, just call our "800" number, give us your FAX number and type of FAX machine, and the information you need from us. We'll FAX it to you immediately.

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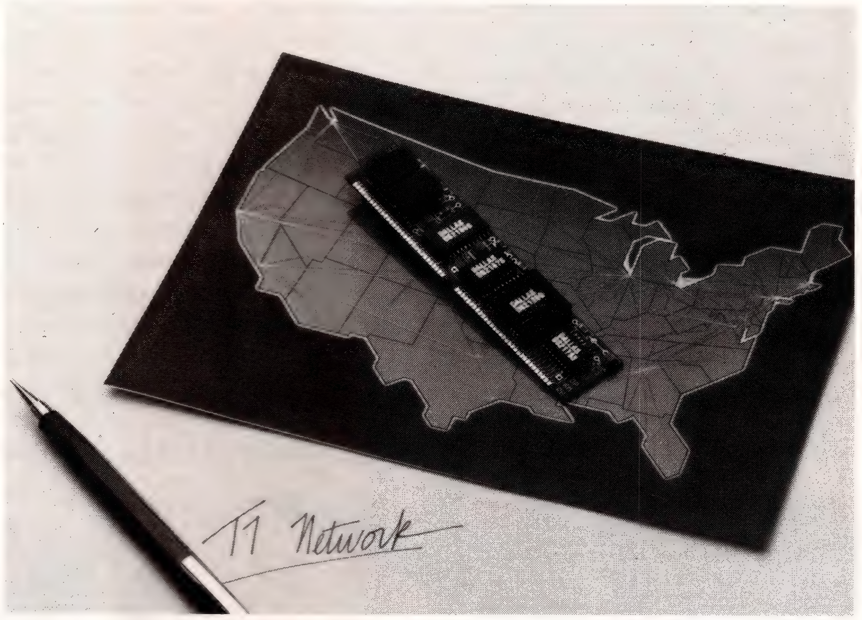
CIRCLE NO 59

Tiny telecommunications module contains a CMOS T1/CEPT line card



Mounted on a circuit board that's about the size of a stick of chewing gum, *the T1/CEPT Line Card from Dallas Semiconductor is the first CMOS chip set that meets both the T1 and CEPT telecommunications standards.*

Touted as the first complete CMOS chip set that meets both the T1 (North American) and CEPT (Conference of European Post Telecommunications) standards, the T1/CEPT Line Card is a circuit-board module that is the size of a stick of chewing gum. Using this module, you have to make only minor modifications to convert your telecommunications equipment for access to either the T1 or the CEPT network, thus providing international-marketing possibilities for your telecommunications equipment.

The circuit comprises four chips mounted in a 0.85×3.85-in. JEDEC configuration that was originally developed for use with dynamic RAMs. The DS2187 receive-line-interface chip interprets incoming signals—after they pass through the module's coupling transformer—and removes any distortion picked up during transmission. The DS2187 uses a laser-trimmed phase-locked loop that continually tracks each signal and passes extracted clock and data information to the DS2180A T1 transceiver.

The transceiver chip formats the data stream according to T1 convention. By replacing the DS2180A with a DS2181A, you can modify the module for use with the CEPT standard. Both transceivers provide line-monitoring capability and allow your equipment to log error conditions and track line performance via a μP port.

The third chip in the module is a DS2175 elastic store that uses a FIFO-buffer memory to resolve any mismatch between the clock of the T1/CEPT network and the clock in your equipment. This chip retains incoming data for delayed release in synchronization with the equipment clock. During transmission, the DS2175 stores outgoing signals for synchronization with the network clock.

The DS2186 transmit-line interface converts square-wave logic signals generated by your equipment to the waveforms specified by the T1/CEPT standards for twisted-pair networks. The manufacturer uses a direct laser-writing technique to set the exact waveform and associated timing in the DS2186. In the event of a revision in either the T1 or the CEPT standard, the manufacturer can replace a single chip to meet the new requirements. Thus, you can concentrate on the design requirements of your equipment rather than preoccupying yourself with changing telecommunications standards.

You can buy the T1/CEPT Line Card for $98 (5000). The manufacturer also offers application notes and $100 designer kits for the chip set.—***J D Mosley***

Dallas Semiconductor, 4350 Beltwood Parkway S, Dallas, TX 75244. Phone (214) 450-0400. TWX 650-244-1669.

Circle No 695

$1995 TMS320C25 DSP in-circuit emulator specs 40-MHz debugging speed

If you've been waiting for a low-cost in-circuit emulator for Texas Instrument's TMS320C25 DSP chip, you should consider the $1995 320C25 ICE (in-circuit emulator) Pak. This unit replaces the target DSP chip in systems under development and lets you perform real-time emulation and debugging at clock speeds reaching 40 MHz. The ICE Pak comes with 16k words of 35-nsec static RAM for zero-wait-state program memory—the unit uses the target DSP's data memory. You can plug the ICE Pak into any host computer or terminal that has an RS-232C port, and you can communicate at a rate as fast as 19.2k baud.

For the basic price, you can buy the unit with communications software and a monitor/debug command set in firmware that includes a disassembler, set and clear breakpoint capability, single-step trace display and modification of memory and I/O parameters, and a command to copy external program ROM to the emulation space. If you need more program memory, you can buy a $2495 version of the ICE Pak that has 64k words of 35-nsec static RAM. Another standard feature lets you modify the emulator's break-handler routine to satisfy special debugging requirements. This feature lets you display not only the usual registers and stack during a break, but also the contents of any eight memory or I/O locations.

You can use the 320C25 DSP ICE Pak with any host computer or terminal *by plugging it into the host's RS- 232C port. The emulator includes a set of monitor and debug commands in firmware, so you don't need any special driver software for host communications.*

The TMS320 Emulator XDS/22, presently marketed by TI for their popular DSP chip, costs seven times as much as the ICE Pak. Part of the reason for the difference in cost is the ICE Pak's compact 3.5×5.6-in. size. The TI emulator is housed in an enclosure that is 25 times larger than the ICE Pak. In addition, the ICE Pak derives its power from the target 320C25 socket—drawing only 25 mA more current than the DSP chip itself—so it needs no separate power supply. Furthermore, the ICE Pak doesn't come with real-time trace capabilities, although for $2995 you can purchase an upgraded version of the ICE Pak that includes 64k words of program memory and 512 words of memory for forward or reverse real-time trace.

The ICE Pak lets you copy the contents of any EPROM program memory from the target system directly into the emulation-program memory space. You can download programs and data files written in TI hex, Intel hex, or binary. The options include a $199 crossassembler for IBM PC or compatible hosts, a $299 crossassembler with an editor for Macintosh hosts, and a $150 evaluation board for IBM PCs that has a ground plane, a crystal, and a 4×5-in. wire-wrap area. The manufacturer offers a 90-day warranty and a 30-day money-back guarantee.—***J D Mosley***

Memocom, 1301 Denton Dr, Suite 204, Carrollton, TX 75006. Phone (214) 446-9906.

Circle No 696

Z I L O G

Z280

The highest performance and highest integration, ever. Together on a single 16-bit chip.

The Z280™ gives you a more powerful CPU and higher performance peripherals than you've ever seen on a 16-bit chip. Think of it as a complete microsystem on a chip.

Unmatched performance...

Start with the most powerful 16-bit engine available, add on-board Cache, MMU and Burst Mode memory support — and you'll begin to understand the Z280's power and potential.

...powerful on-board peripherals...

Imagine the savings in cost and board size when you have peripherals like 4 DMA channels that'll give you transfers at 6.6 Mbytes/sec, and a full-duplex UART.

...and the glue to tie it all together.

With a DRAM Controller to support up to 1 MBit DRAMs and Programmable Wait State Logic — on board — you're really looking at significant glue reduction.

	Z280™	80186	68070
Package	68-pin PLCC/CMOS	68-pin LCC/NMOS	84-pin PLCC/CHMOS
Typical Power	375 mW	2 W	800 mW (est)
Speed	10-25 MHz	8-12.5 MHz	10 MHz
Memory Support	16 Mb Physical Paged	1 Mb Physical Segmented	16 Mb Physical 8 or 128 Segments
16-bit Registers	12 General	8 General	15 Dedicated
Instruction Pre-fetch	256-Byte Assoc. Cache; Burst Mode	6-Byte Queue	None
Multiprocessor Support	Local or Global	Local only	Local only
Wait Logic	Programmable	Programmable	Hardwire
DMA	4 Channels, 6.6 Mb/s @ 10 MHz	2 Channels 2 Mb/s @ 8 MHz	2 Channels, 3.2 Mb/s @ 10 MHz
Counter/Timers	3 16-bit	3 16-bit	2 16-bit
Serial I/O	1 Full-Duplex UART	None	1 Full-Duplex UART
DRAM Controller	10-bit Refresh	None	None
Price (100)	$33	$43	$50

Z280: Truly a microsystem.

The Z280 gives you a lot more performance. In a lot less board space. All off the shelf and backed by Zilog's proven quality and reliability. Plus, it's binary code-compatible with the Z80,® and priced to rival 8-bit chips. And all the development support tools you need are available from industry leaders. Contact your local Zilog sales office or your authorized distributor today. Seeing is believing. Zilog, Inc., 210 Hacienda Ave., Campbell, CA 95008 (408) 370-8000.

The choice is clear.

Right product. Right price. Right away.

ZILOG SALES OFFICES: CA (408) 370-8120, (714) 432-9971, (818) 707-2160, **CO** (303) 494-2905, **FL** (813) 585-2533, **GA** (404) 923-8500, **IL** (312) 885-8080, **MA** (617) 273-4222, **MN** (612) 831-7611, **NJ** (201) 288-3737, (609) 778-8070, **OH** (216) 447-1480, **TX** (214) 231-9090, **CANADA** Toronto (416) 673-0634, **ENGLAND** Maidenhead (44) (628) 781227, **W. GERMANY** Munich (49) (89) 612-6046, **JAPAN** Tokyo (81) (3) 587-0528, **HONG KONG** Kowloon (852) (3) 723-8979. **R.O.C.:** Taiwan (886) (2) 731-2420, **U.S. AND CANADA DISTRIBUTORS:** Anthem Electric, Bell Indus., Graham Elec., Hall-Mark Elec., JAN Devices Inc., Lionex Corp., Schweber Elec., Western Microtech., **CANADA** Future Elec., SEMAD.

Zilog
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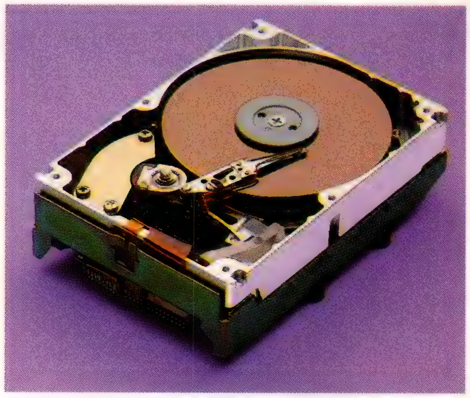
EXXON Corporation

"I shop the specs

because it's my job. But I buy the product because it's my career."

WHAT YOU SHOULD KNOW ABOUT THE NEW PRODRIVE™ SERIES OF 3½-INCH HARD DISK DRIVES FROM QUANTUM.



The numbers are the easy part. Either a product has them or it doesn't.

But you can't build a system out of specs.

You also need dedicated product-support people who will sit down and help you solve some tough engineering problems and put those specs to work.

Quantum is ready to deliver both.

Our new ProDrive Series of 3½-inch hard disk drives offers you the broadest range of capacities in the broadest range of interfaces in the industry. 42 and 84 megabyte formatted with embedded SCSI interface right now. And later this year, up to 168 megabytes, in SCSI, ESDI, and AT-Bus. Ten new drives in all.

All with access times of 19 ms or less.

With synchronous data transfers to the SCSI bus of 4 megabytes per second, and asynchronous data transfers of 2 megabytes per second.

With an MTBF of 50,000 hours.

And with DisCache,™ Quantum's unique 64 kilobyte data-buffering scheme that can make our 19-ms drive perform like a 12-ms drive—or even faster, depending on your application.

But Quantum also offers you the people who can help you put those numbers to work in your own system. A dedicated team of engineering professionals who understand the particular needs of the systems designer—and can help meet those needs quickly, efficiently, cost-effectively.

The new ProDrive Series. The specs you want. The support you need.

That's what Quantum delivers.

INTRODUCING THE PRODRIVE SERIES
- *3½-inch form factor*
- *42, 84, 103, 120, 145, 168 MBs formatted*
- *SCSI, ESDI, AT-Bus*
- *19 ms or faster average access time*
- *64 KB buffer with exclusive DisCache™*
- *50,000-hour MTBF*
- *42, 84 MB SCSI evaluation units AVAILABLE NOW*
- *42, 84 MB AT-Bus units available early summer '88*

Quantum

Quantum Corporation
1804 McCarthy Blvd.
Milpitas, CA 95035

Microprocessor Support Made Simple

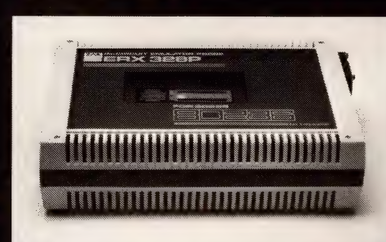
Now, ZAX simplifies microprocessor design, integration and testing with their advanced line of ERX- and ICD-series emulators. You simply tell us the processor that drives your design and we tailor a development system especially for your environment, including full software support.

Our ERX-series emulators provide over *80 debugging commands, with 256,000 hardware breakpoints, real-time performance analysis, high-level language debug and trace analysis* of program execution while you emulate in real-time. And they interface directly to your personal computer (AT-class) to provide you with a complete host development station and emulation manager. This consolidated approach utilizes industry-standard equipment and eliminates the use of a proprietary dedicated chassis.

ZAX established the benchmark for standalone emulation tools when they introduced their versatile line of ICD-series emulators. Completely flexible, ICD-series emulators can be interfaced to *either a simple terminal or host computer* (from pc to mainframe) depending on your requirements. This makes them ideal for both *in-house development* and *on-site testing.*

Simplify support for your microprocessor development projects with the help of ZAX! Call today to arrange a product demonstration or write for complete details about our product line. Call us TOLL FREE at 800-421-0982 (in California phone 800-233-9817) or write to ZAX CORPORATION, 2572 White Road, Irvine, CA 92714.

In Europe, call United Kingdom: 0628 476 741, West Germany: 02162-3798-0, France: (03) 956-8142, Italy: (02) 688-2141.



ZΛX
Zax Corporation

CIRCLE NO 62

Saratoga FIFOs.

Our new FIFOs are the world's fastest. Available now in 10, 15, 25, 40 and 50 MHz.

Slow interprocessor communication headaches. You thought you'd tried every buffering remedy in the book to get rid of them.

But here's one you haven't: *raw FIFO speed.* Using Saratoga's new family of BiCMOS FIFOs—the world's first 50-MHz first-in, first-out memories.

Organized as 64 words by-4 and by-5 bits wide, these RAM-based devices deliver performance unmatched in the industry—at 10, 15, 25, 40 and 50 MHz.

Even so, they consume no more power than CMOS FIFOs, while offering high output drive that's TTL compatible. And they can be cascaded to expand in word width and depth. Plus they're available in both commercial and military temperature ranges, in industry-standard pin-outs.

This new generation of FIFOs will soon include 64 by 9 and larger density 512, 1K and 2K by 9 devices. Joining Saratoga's existing lines of high-performance TTL and ECL static RAMs—also among the fastest now available. And all made possible by our proprietary BiCMOS technology—SABIC™—which combines the best of both the bipolar and CMOS worlds.

So if system timing headaches have got you down, take one of our new FIFO buffers. And call us in the morning: (408) 864-0500. Or write: Saratoga Semiconductor, 10500 Ridgeview Court, Cupertino, CA 95014.

Saratoga FIFO Memories	
Clock Frequency	50 MHz (40 MHz military)
Data Access Time	15 nsec
Data Set-up and Hold Time	3 nsec
Bubble-through Time	25 nsec (max)
Power Consumption	385 mW
Output Drive	16 mA

Saratoga Semiconductor

The Technology Leader in BiCMOS

CIRCLE NO 63

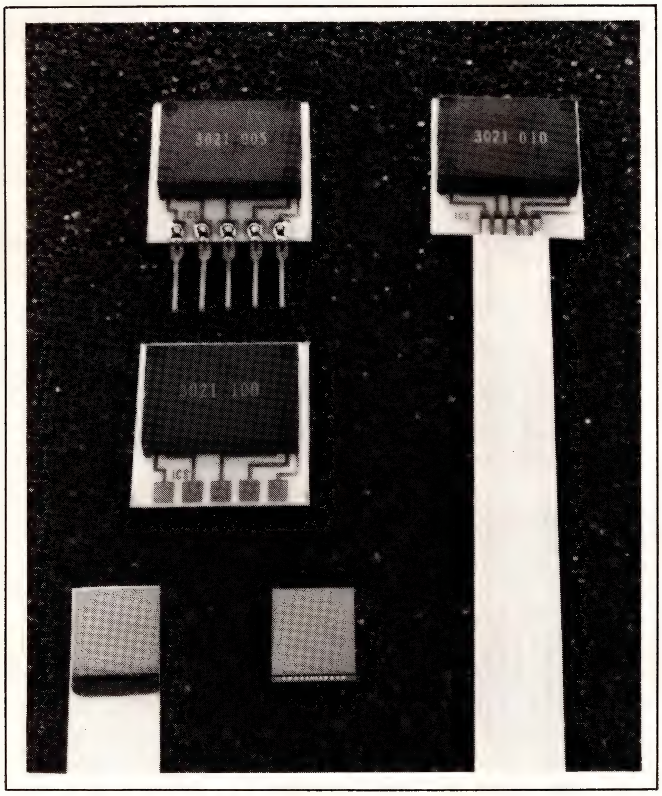
Introducing The First 50-MHz FIFOs. In BiCMOS.

READERS' CHOICE

Of all the new products covered in EDN's **January 21, 1988,** issue, the ones reprinted here generated the most reader requests for additional information. If you missed them the first time, find out what makes them special: Just circle the appropriate numbers on the Information Retrieval Service card, use EDN's Express Request Service, or refer to the indicated pages in our **January 21, 1988,** issue.

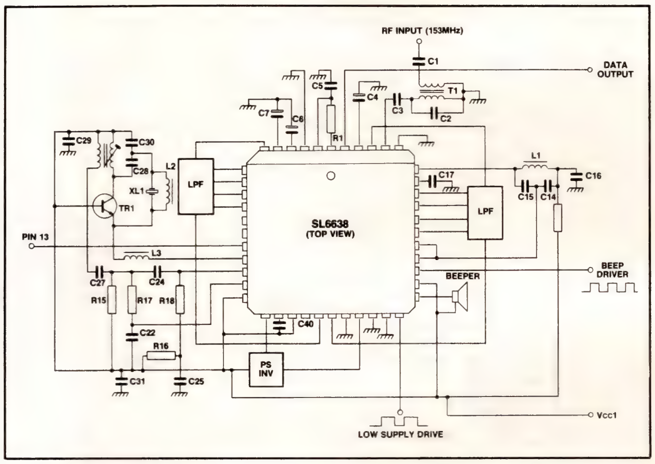
MATH SOFTWARE

The MathMate integrated mathematical-software package provides an equation solver and expression analyzer and runs on the IBM PC and compatibles (pg 243).
MCAE Technologies Inc
Circle No 606



▲ ACCELEROMETER

Model 3021 monitors acceleration, vibration, and shock. It measures 7.9×7.3-mm and is well suited to applications characterized by limited sensor-mounting area (pg 234).
IC Sensors Inc
Circle No 604



▲ RADIO IC

The SL6638 is a single-chip radio receiver designed for battery-powered time and data-paging equipment that operates at broadcast frequencies as high as 200 MHz (pg 229).
Plessey Semiconductors Ltd
Circle No 602
Plessey Semiconductors
Circle No 603

TERMINAL

The pocket-size Multiportable terminal lets you read, write, and program a Memocard smart card that contains an 8-bit μP and 2k or 8k bytes of EEPROM (pg 94).
Multimil Inc
Circle No 601

◀ EMULATOR

The in-circuit emulators in the MicroIce family connect to IBM PCs and compatible computers and support the 8051 family. They provide the same features as the vendor's earlier units, but at approximately half the cost (pg 240).
MetaLink Corp
Circle No 605

We engineer ours on
with a passion for pe

While some companies sell a lot of computers because they make something for everyone, we sell a lot because we don't.

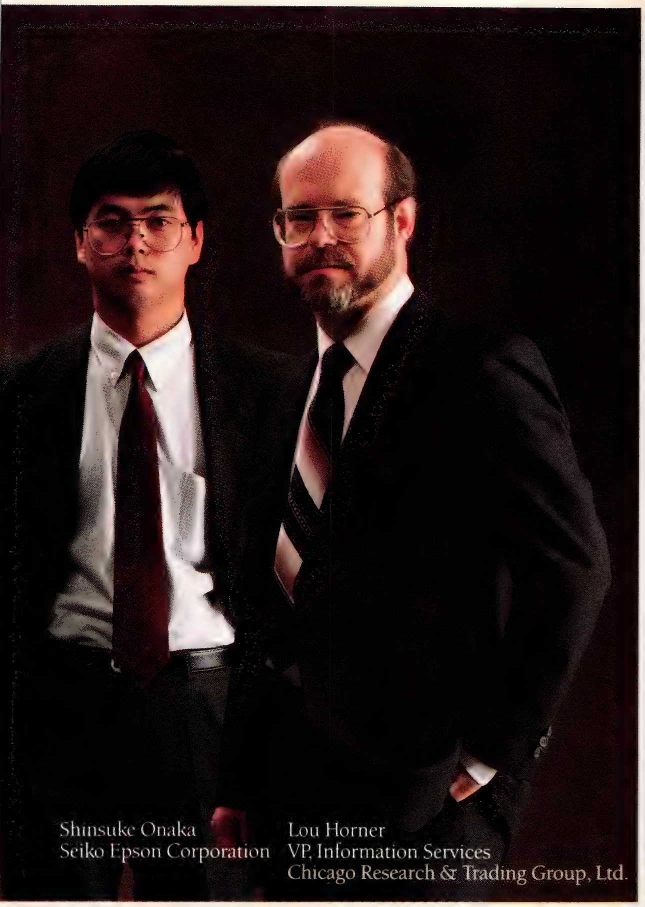
All the workstations we make, the applications that run on them, and the networking power that unites them with the other computers in your company were created for a select group of people.

Namely the engineers, product designers, software developers and other professionals who demand nothing less than ultimate compute performance.

People who clamor for access to processing power and graphics. Who possess an insatiable appetite for information. And who can ill afford to endure the delays, limitations and obstacles that typically hinder the effort to attain it.

If you're such a person, you should have an Apollo workstation. For you'll realize the moment its screen is in front of you that the issue of performance is behind you.

An Apollo workstation will grant upon you enough dedicated compute power to keep your imagination charged permanently. Letting you choose from a compatible family of workstation systems whose prices start as low as a personal computer and whose perfor-



y for those formance.

mance extends to that of supercomputers.

These machines will grant you imagery so brilliant you won't want to blink for fear of missing something. With real time two- and three-dimensional graphics that render up to 16.7 million colors at 130,000 vectors per second. And they'll open your eyes even wider with networking power and elegance.

Every Apollo workstation, from the Series 3000™ Personal Workstation™ to our new Personal Supercomputer,™ functions as a command center from which you have unequalled access to data, processing power, development tools, and applications.

So that every mainframe, minisuper, and microcomputer on your network is at your beck and call.

In a manner almost invisible to you, our workstations show you networking performance you probably thought impossible.

For with the industry's first implementation of Network Computing Architecture,™ they make your multi-vendor network appear as one computing environment.

Letting you run a single application on a network of computers by automatically dispatching portions of a program to the processors most qualified to execute them. And providing the tools to develop and debug code running on different machines.

All while freeing you to create applications, access network resources and even move from one operating environment to another with whatever language, menus and file names you define.

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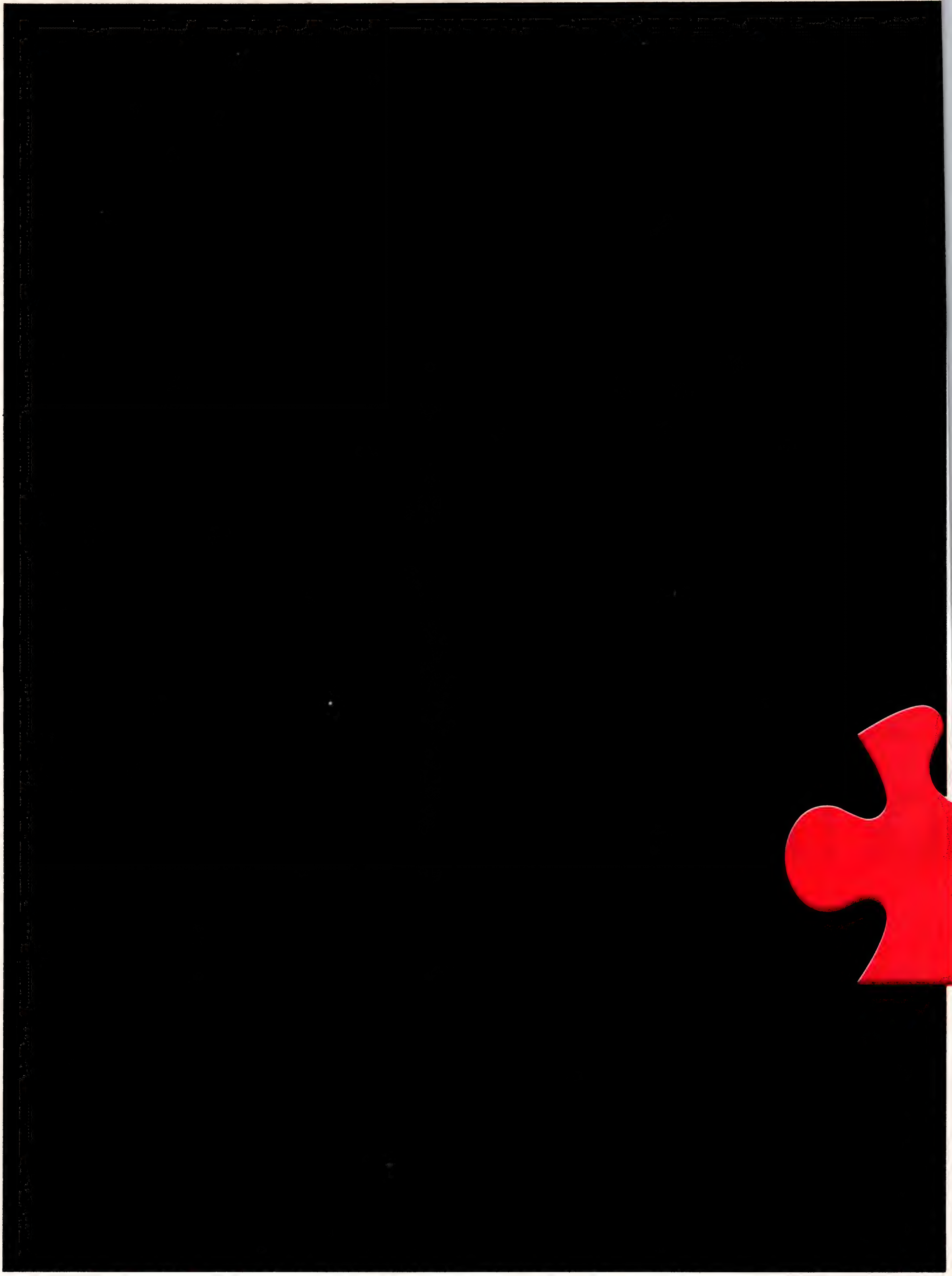
For more information, call 1-800-323-1846. In Massachusetts call 1-800-847-1011. Or write Apollo, 330 Billerica Road, Chelmsford, MA 01824.



LEADTIME INDEX

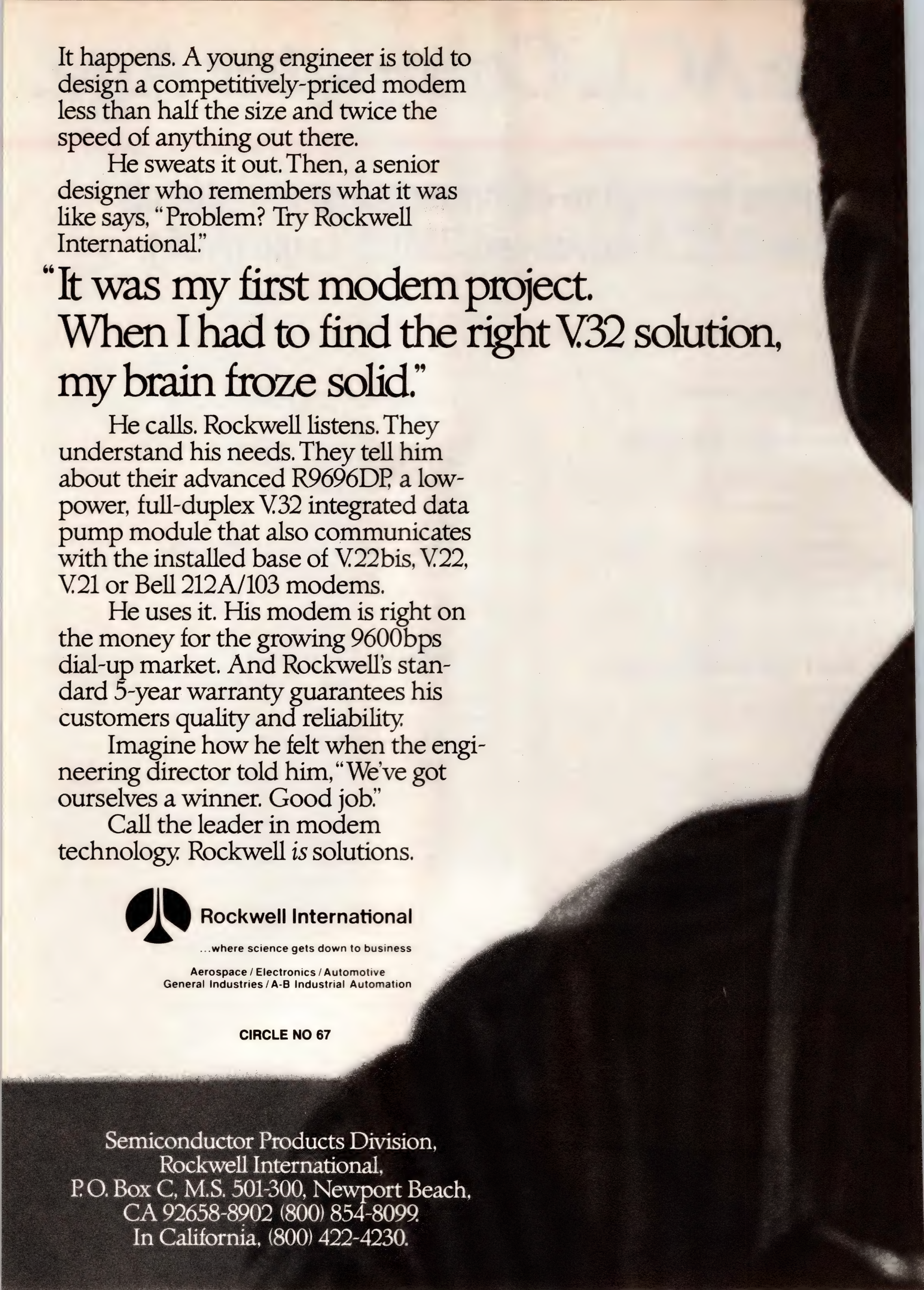
Percentage of respondents

ITEM	Off the shelf	1-5 weeks	6-10 weeks	11-20 weeks	21-30 weeks	Over 30 weeks	Average (weeks)	Last month's average (weeks)
TRANSFORMERS								
Toroidal	6	23	47	18	6	0	7.2	7.3
Pot-Core	0	8	67	17	8	0	10.3	7.8
Laminate (power)	5	45	27	14	9	0	7.6	8.3
CONNECTORS								
Military panel	0	0	73	27	0	0	10.2	10.8
Flat/Cable	22	39	30	9	0	0	4.6	5.6
Multi-pin circular	9	25	25	25	8	8	8.6	9.4
PC (2-piece)	7	29	50	14	0	0	6.8	7.4
RF/Coaxial	10	50	35	5	0	0	4.6	5.3
Socket	23	54	14	9	0	0	3.6	4.7
Terminal blocks	32	59	4	5	0	0	2.3	5.4
Edge card	24	33	38	5	0	0	4.5	5.7
D-Subminiature	20	40	35	5	0	0	4.4	5.1
Rack & panel	22	36	21	21	0	0	5.8	6.4
Power	20	27	40	13	0	0	5.8	5.5
PRINTED CIRCUIT BOARDS								
Single-sided	0	47	48	5	0	0	5.6	5.4
Double-sided	0	48	48	4	0	0	5.4	5.8
Multi-layer	0	25	63	12	0	0	7.5	7.5
Prototype	0	79	13	8	0	0	3.9	4.3
RESISTORS								
Carbon film	49	27	14	10	0	0	3.3	4.2
Carbon composition	29	38	14	19	0	0	4.9	4.0
Metal film	31	35	26	8	0	0	4.1	4.4
Metal oxide	23	38	31	8	0	0	4.5	4.6
Wirewound	10	32	32	26	0	0	7.4	8.8
Potentiometers	24	40	60	16	0	0	5.0	6.1
Networks	27	32	27	14	0	0	5.0	6.3
FUSES	38	38	19	5	0	0	3.1	4.4
SWITCHES								
Pushbutton	24	43	28	5	0	0	3.9	5.8
Rotary	21	32	37	5	5	0	5.7	6.1
Rocker	11	47	32	10	0	0	5.1	5.4
Thumbwheel	6	22	55	6	11	0	8.7	7.7
Snap action	8	38	46	8	0	0	5.7	6.5
Momentary	17	33	39	11	0	0	5.5	6.3
Dual in-line	13	50	31	6	0	0	4.4	6.6
WIRE AND CABLE								
Coaxial	27	41	27	5	0	0	3.8	4.2
Flat ribbon	35	42	19	4	0	0	3.0	5.5
Multiconductor	22	50	17	11	0	0	4.1	4.6
Hookup	56	33	7	4	0	0	1.9	3.2
Wire wrap	31	50	12	6	0	0	2.9	4.2
Power cords	35	38	23	0	4	0	3.6	5.9
POWER SUPPLIES								
Switcher	11	17	50	11	11	0	9.0	7.4
Linear	11	33	45	11	0	0	6.0	7.7
CIRCUIT BREAKERS	6	26	42	26	0	0	8.0	8.0
HEAT SINKS	25	32	43	0	0	0	4.1	5.1
RELAYS								
General purpose	24	19	38	14	5	0	7.0	6.1
PC board	19	33	26	22	0	0	6.3	7.2

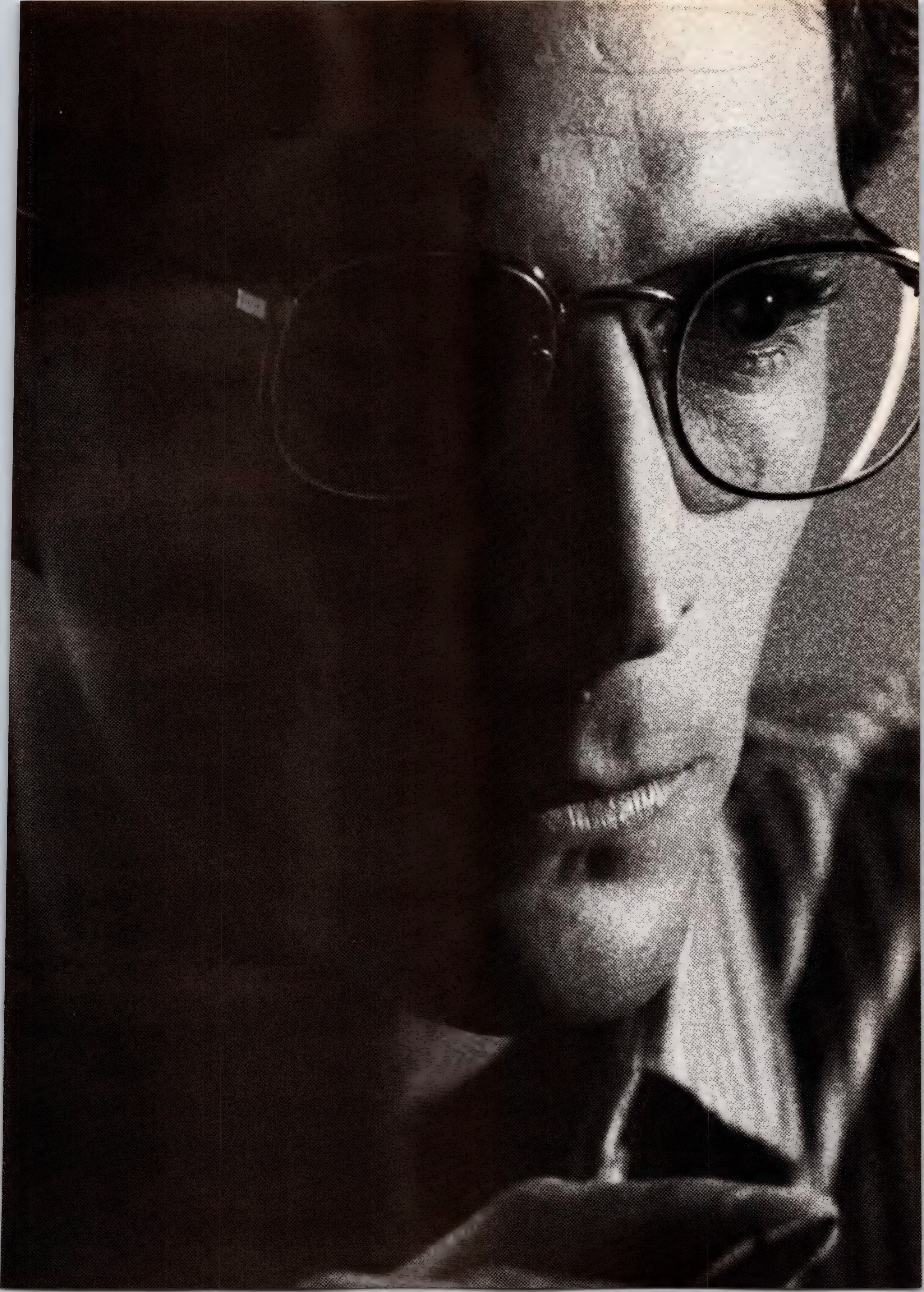
ITEM	Off the shelf	1-5 weeks	6-10 weeks	11-20 weeks	21-30 weeks	Over 30 weeks	Average (weeks)	Last month's average (weeks)
RELAYS								
Dry reed	27	20	27	26	0	0	6.7	8.6
Mercury	20	20	30	30	0	0	7.6	9.1
Solid state	12	35	35	18	0	0	6.4	8.9
DISCRETE SEMICONDUCTORS								
Diode	37	27	18	12	3	3	5.6	7.0
Zener	37	19	18	18	4	4	7.0	7.3
Thyristor	11	21	47	11	5	5	8.8	8.8
Small signal transistor	30	10	20	30	5	5	9.5	7.4
MOSFET	10	35	20	30	0	5	8.7	10.2
Power, bipolar	19	25	19	31	0	6	8.8	9.3
INTEGRATED CIRCUITS, DIGITAL								
Advanced CMOS	12	19	44	25	0	0	7.9	9.6
CMOS	19	23	27	27	4	0	8.0	7.1
TTL	39	22	17	17	5	0	5.8	6.5
LS	33	29	14	19	5	0	6.0	5.9
INTEGRATED CIRCUITS, LINEAR								
Communication/Circuit	23	15	46	16	0	0	6.5	8.7
OP amplifier	23	14	36	18	5	4	8.6	6.3
Voltage regulator	27	11	35	19	4	4	8.3	7.2
MEMORY CIRCUITS								
RAM 16k	13	20	33	27	0	7	9.5	9.7
RAM 64k	11	37	16	31	0	5	8.5	8.8
RAM 256k	0	25	38	25	6	6	11.0	10.0
RAM 1M-bit	0	17	33	33	0	17	14.4	12.5
ROM/PROM	0	17	25	50	8	0	12.4	11.0
EPROM 64k	17	28	17	33	5	0	8.5	9.5
EPROM 256k	7	20	20	53	0	0	10.5	9.3
EPROM 1M-bit	0	18	27	46	9	0	12.2	11.6
EEPROM 16k	0	22	14	64	0	0	11.8	10.6
EEPROM 64k	0	19	25	56	0	0	11.3	10.9
DISPLAYS								
Panel meters	7	21	43	29	0	0	8.5	6.7
Fluorescent	0	18	27	55	0	0	11.3	8.5
Incandescent	20	40	10	30	0	0	6.4	6.5
LED	32	20	36	12	0	0	5.2	8.1
Liquid crystal	0	12	44	44	0	0	10.8	10.5
MICROPROCESSOR ICs								
8-bit	24	18	29	29	0	0	7.3	7.6
16-bit	6	25	19	50	0	0	10.0	9.3
32-bit	0	15	15	62	8	0	13.5	7.6
FUNCTION PACKAGES								
Amplifier	20	20	30	30	0	0	7.6	6.4
Converter, analog to digital	7	29	28	36	0	0	8.6	8.6
Converter, digital to analog	0	46	27	27	0	0	7.4	9.2
LINE FILTERS	13	20	40	27	0	0	7.9	9.4
CAPACITORS								
Ceramic monolithic	17	25	46	12	0	0	6.1	5.8
Ceramic disc	30	30	22	18	0	0	5.2	5.1
Film	14	38	19	24	5	0	7.4	4.8
Aluminum electrolytic	19	23	35	23	0	0	6.9	4.8
Tantalum	24	32	32	8	4	0	5.5	6.2
INDUCTORS	5	37	42	16	0	0	6.7	9.3

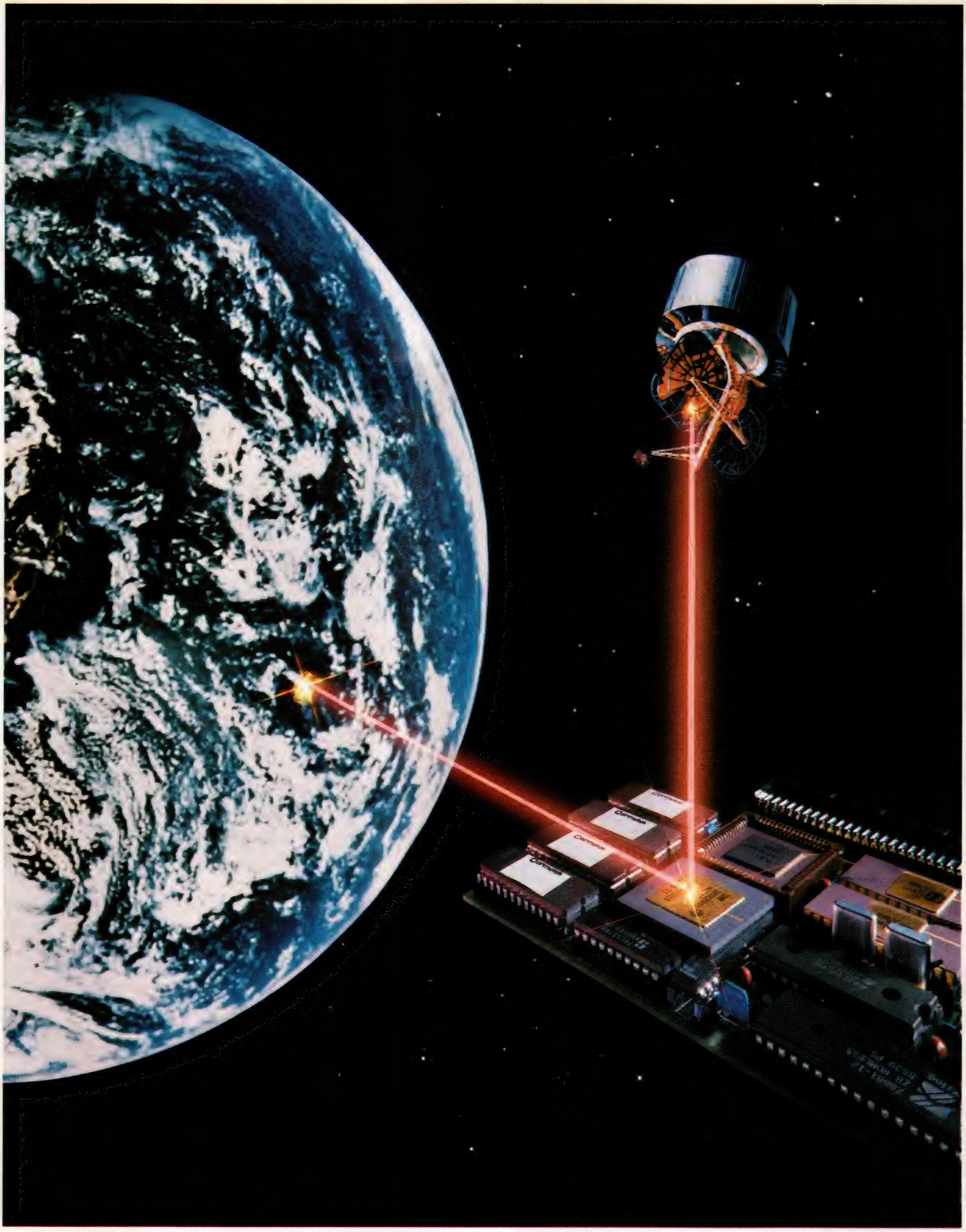
Source: *Electronics Purchasing* magazine's survey of buyers

Your next destination:



It happens. A young engineer is told to design a competitively-priced modem less than half the size and twice the speed of anything out there.
He sweats it out. Then, a senior designer who remembers what it was like says, "Problem? Try Rockwell International."
"It was my first modem project. When I had to find the right V.32 solution, my brain froze solid."
He calls. Rockwell listens. They understand his needs. They tell him about their advanced R9696DP, a low-power, full-duplex V.32 integrated data pump module that also communicates with the installed base of V.22bis, V.22, V.21 or Bell 212A/103 modems.
He uses it. His modem is right on the money for the growing 9600bps dial-up market. And Rockwell's standard 5-year warranty guarantees his customers quality and reliability.
Imagine how he felt when the engineering director told him, "We've got ourselves a winner. Good job."
Call the leader in modem technology. Rockwell *is* solutions.
Rockwell International
...where science gets down to business
Aerospace / Electronics / Automotive
General Industries / A-B Industrial Automation
CIRCLE NO 67
Semiconductor Products Division,
Rockwell International,
P.O. Box C, M.S. 501-300, Newport Beach,
CA 92658-8902 (800) 854-8099.
In California, (800) 422-4230.





As the trend of integrating modem functions on single ICs continues, *more and more chips will be available to provide worldwide communications via satellite. (Photo courtesy Cermetek)*

Special Report

Single-IC modems

Integrating all the functions of a modem on a single IC has made it feasible to implement a virtual front-end processor for the PSTN. Even so, you'll still have to make provision for a μcontroller and, in some cases, the 2- to 4-wire hybrid and the DAA.

John Gallant, *Associate Editor*

Single-IC modems are eliminating board-level modems that transmit at 1200 bps or less. Indeed, even single-IC modems that operate at 2400 bps are available. A recent Electronic Trend Publications' study (**Ref 1**) predicts that numerous applications for these chip-level modems will emerge: inventory status for vending machines, data telemetry for home or laboratory instruments, security monitors, credit-card terminals, and order entry for portable computers. Essentially, by adding a single-IC modem to your embedded application, you can have a virtual front-end processor for communicating over the public switched-telephone network (PSTN) or via a communication satellite link.

How do you define a single-IC modem?

The definition of a single-IC modem is clouded, however, because some manufacturers place all of the modem functions in a single chip, others place multiple chips in a hybrid module, and still others place more than one chip on a single substrate. Regardless of the configuration, all single-IC modems also require a μcontroller to execute the modem command set and handshake protocols; this being the case, some manufacturers have opted to transfer some of the modem functions to the external controller. Further, achieving a complete modem usually requires the addition of a 4- to 2-wire hybrid and a data-access arrangement (DAA) for connection to the PSTN.

Most of today's single-IC modems provide the following functions: modulation/demodulation (of course), transmit and receive filtering, μcontroller interfacing, serial-port interfacing, asynchronous-to-synchronous conversion circuitry, scrambling and descrambling (if required), and clock generation. Most also have automatic gain control (AGC) to normalize the 45-dB dynamic range of received signals, and most have answer and call-progress tone detectors along with dial-tone multiple-frequency (DTMF) generators. In addition, many include UARTs, loop-back test modes, audio outputs, answer- and guard-tone generators, line equalizers, A/D and D/A converters, and digital signal processors.

Single-IC modems must interface with a μcontroller: Connecting an interrupt line on the μcontroller to the ring line on the DAA enables the detection of a ring signal. A routine in the controller, which toggles the on/off hook command line to the DAA at the proper time intervals, effects the pulse dialing. The single-IC devices primarily support Bell 212A and 103 North American standards and CCITT international standards such

The industry trend is to combine all the functions of a modem in a single IC.

as V.21, V.22, and V.23, which govern 1200-bps and 0- to 300-bps communications (see **box,** "Modulation techniques and speed characterize modems"). Single-chip modems that support the CCITT V.22bis standard for 2400-bps communications are also emerging, however.

True 1-chip modems are available

The Am79C12 from Advanced Micro Devices is a representative example of a single-IC modem that performs all modem functions on one chip. Because the Am79C12 contains an integral 4- to 2-wire hybrid, you only have to add a μcontroller and a DAA to configure a complete 300- to 1200-bps modem **(Fig 1)**. It conforms to Bell 212A and 103 modem specifications, and it contains all the modulation, demodulation, filtering (digital), and A/D and D/A functions for both the transmitter and receiver. The chip also has a DTMF tone generator, a UART, a call-progress tone-detection circuit, and analog and remote-digital loop-back test modes. You can switch in a compromise equalizer to compensate for line distortions. The device comes in either a 44-pin PLCC (plastic leaded chip carrier) or a 40-pin plastic DIP.

AMD has dubbed its Am79101 a World-Chip because it supports both the North American Bell 202 and 103 and the international CCITT V.21 and V.23 specifications. The FSK modem chip contains answer-tone and DTMF generators for DTMF-tone autodialing. When operating in the V.23 mode, it can transfer data in the back channel at 150 bps. The unit contains a 4- to 2-wire hybrid and uses digital signal processing (DSP) for filtering and modulation and demodulation functions. The device is available in either a 28-pin DIP or PLCC.

Silicon Systems also has a couple of single-chip modems that are in the world class family. The K222 combines Bell 212A and 103 and CCITT V.22 and V.21 capability, and the K224 provides 2400-bps CCITT V.22bis operation along with V.22 and V.21 and Bell 212A and 103 modes. By incorporating these standards, each of the chips is able to provide worldwide communications capabilities at 1200 bps. And, the two K Series members are plug compatible and upgradable with all other K Series devices. None of the K Series of single-chip modems puts the 4- to 2-wire hybrid on chip, however; **Fig 2** shows the typical circuitry necessary to build a complete modem with any of the devices in this

Modulation techniques and speed characterize modems

The Bell and the CCITT standards specify the respective data-transmission speeds for modems in North America and internationally **(Table A)**. The Bell 103 and 113 and the CCITT V.21 frequency assignments define full-duplex, 0- to 300-bps FSK operation. Data transmission is asynchronous only. The mark and space frequencies for these standards are not the same, and you must account for these differences if you want to connect a modem using the North American standard to a modem using the international standard.

The Bell 202 and the CCITT V.23 standards define the frequencies for half-duplex, 1200-bps FSK operation. The CCITT V.23 standard also provides a fallback mode to 600 bps. According to these standards, a modem can transmit and receive asynchronous data, but not simultaneously, over 2-wire phone lines. To change a call's direction, the modem must signal the far-end modem to indicate a reversal—a technique called line turnaround. To avoid this inefficiency, the standards allot a

TABLE A—SPEED AND MODULATION CHARACTERISTICS

SPEED (bps)	2-WIRE MODE	MODULATION	SPECS
0 TO 300	FULL DUPLEX	FSK, ASYNCHRONOUS	BELL 103, 113 CCITT V.21
0 TO 1200	HALF DUPLEX (WITH BACK CHANNEL)	FSK, ASYNCHRONOUS	BELL 202 CCITT V.23
1200	FULL DUPLEX	QPSK, SYNCHRONOUS	BELL 212A CCITT V.22
2400	FULL DUPLEX	QAM, SYNCHRONOUS	CCITT V.22bis
4800	HALF DUPLEX	QAM, SYNCHRONOUS	BELL 208 CCITT V.27
9600	HALF DUPLEX	QAM, SYNCHRONOUS	BELL 209 CCITT V.29

(SOURCE: ADVANCED MICRO DEVICES)

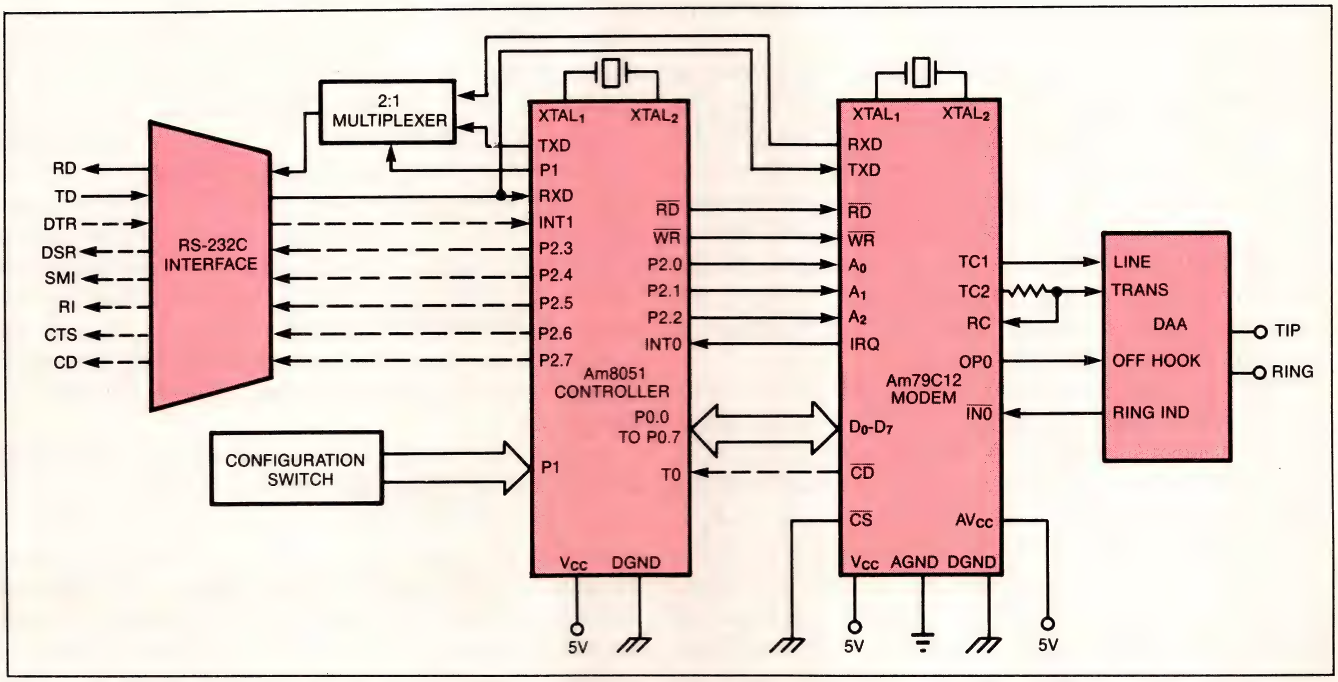


Fig 1—The Am79C12 modem has all its modem functions on one chip. *You only have to add a µcontroller and a DAA to have a complete 1200-bps modem.*

small portion of the bandwidth as a back or reverse channel. The modem can transmit data in the back channel at a lower rate in the direction opposite to, but simultaneous, with the main channel.

The Bell 212 and the V.22 standards define the frequency assignments for full-duplex, 1200-bps operation. These standards use quad PSK (QPSK) modulation to modulate a 1200-Hz originate frequency and a 2400-Hz answer frequency. They require that two successive data bits be encoded as dibits, which perform QPSK modulation of the transmit carrier frequency at a 600-baud rate. The transmitter uses a self-synchronizing scrambler to implement a $1+X^{-14}+X^{-17}$ polynomial generator to spread energy over the allocated bandwidth. A descrambler at the receiver recovers the scrambled data.

Under these two standards, data transmission can be either synchronous or asynchronous. In the asynchronous mode, data is sent to an asynchronous-to-synchronous converter, which deletes or inserts stop bits to transmit data at a regular rate. The receiver has a synchronous-to-asynchronous converter, which reinserts any deleted stop bits.

The Bell 212 and the V.22 standards differ in the handshake sequence of detecting the originating modem's speed and disconnection. In addition, the CCITT V.22 specification calls for guard tones at 1800 Hz and 550 Hz and an answer tone at 2100 Hz. The Bell 212A specification calls for an answer tone at 2225 Hz.

The CCITT V.22bis standard defines the frequency assignments for full-duplex, 2400-bps, QAM (quad amplitude modulation) operation. According to QAM operation, the data is sent to a 4-level amplitude modulator for quad-bit encoding. The encoded data is phase modulated at a 1200-Hz originate frequency and a 2400-Hz answer frequency. Phase modulation occurs at a 600-baud rate, which creates a 16-point constellation diagram. This modulation scheme requires a complex demodulator at the answer end and adaptive-equalization networks to adapt to line variations.

By adding a single-IC modem to your embedded application, you can have a virtual front-end processor.

family. The 2-operational-amplifier duplexer performs the 4- to 2-wire hybrid function.

The K222 integrates analog, digital, and switched-capacitor filtering on a single substrate. The chip includes a DTMF tone generator, 550-Hz and 1800-Hz guard-tone generators, call-progress tone-detection circuitry, answer-tone generators, and numerous test modes, including analog loop back (ALB) and remote digital loop back. (For definitions for some of the specialized terms you'll come across in this article, see **box,** "Glossary of modem terminology.") You have a choice of either a 22- or 28-pin DIP.

The K224 provides 2400-bps operation as defined by the CCITT V.22bis standard with fallback to the lower speeds of both the Bell 212A and 103 and CCITT V.22 and V.21 standards. Containing all the features of the K222 chip along with a QAM (quad amplitude modulation) modulator and demodulator, the chip provides selectable compromise equalizers for 1200-bps operation and adaptive equalizers for 2400-bps operation. In addition to a serial data interface, it has an 8-bit multiplexed address/data bus for interfacing with an 8-bit μcontroller.

The MP8512 from Micro Power Systems is another world-class single-chip modem, conforming to Bell 212A, 103, and 113, and CCITT V.22 (A, B) and V.21 specifications. Its built-in 4- to 2-wire hybrid requires an external resistor between the transmit and receive pins. The device has DTMF generators, call-progress tone detectors, a UART, and internal control and status registers accessible through a μP bus interface. Data sent to the control registers sets the transmission speed, Bell or CCITT modes, and parity; data in the status registers indicates carrier detection, line quality, and detection of a break signal. The chip resides in a 40-pin DIP.

Exar's XR-2130 single-chip modem meets Bell 212A and CCITT V.22 specifications. The chip interfaces with either an XR-2131 modem controller or an 80C31 controller and software supplied by Exar. Instead of modulating with discrete phase jumps, the dibit-encoded information gradually phase modulates the carrier, which allows a digital echo-modulation circuit to precisely shape the transmit carrier frequency. A Cos-

Text continued on pg 126

REPRESENTATIVE MANUFACTURERS OF SINGLE-MODEM ICs

		STANDARDS												
		BELL			CCITT									
COMPANY	DEVICE	103	202	212A	V.21	V.22	V.22BIS	V.23	POWER SUPPLIES	POWER DISSIPATION	UART	DTMF	DUPLEXER	DAA
ADVANCED MICRO DEVICES	Am7910	•	•		•			•	5V −5V	500 mW				
	Am7911	•	•		•			•	5V −5V	500 mW				
	Am79C12	•		•					5V	300 mW	•	•	•	
	Am79101	•	•		•			•	5V −5V	500 mW		•	•	
CERMETEK	CH1760A	•		•					5V −12V	650 mW		•	•	•
	CH1760E	•		•					12V −12V 5V	280 mW		•	•	•
	CH1770	•		•					5V −5V	600 mW		•	•	•
	CH1780	•		•	•	•	•		5V −12V	350 mW		•	•	•
	CH1765								12V 5V −12V	280 mW		•	•	•
EXAR	XR-2100				•				5V −5V	200 mW				
	XR-2130	•		•		•			5V −5V	200 mW		•		

NOTES: 1. ALB = ANALOG LOOP BACK; DLB = DIGITAL LOOP BACK.
2. PLCC = PLASTIC LEADED CHIP CARRIER.
3. SCF = SWITCHED CAPACITOR FILTER.

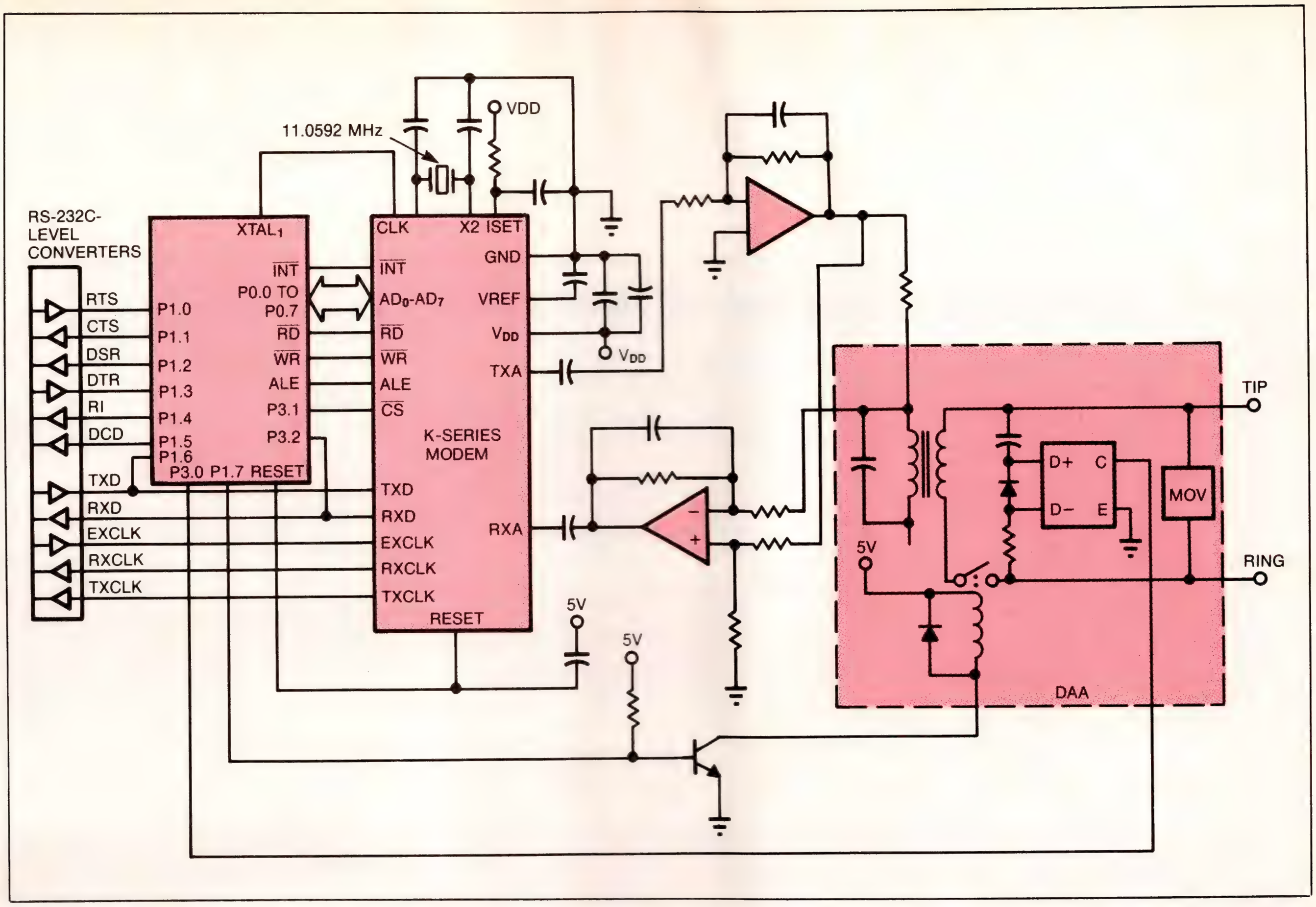


Fig 2—The K Series of single-chip modems from SSI come in packages with identical pinouts. The addition of a controller, a duplexer, and a DAA completes the design.

FILTER TYPES	AGC	CALL-PROGRESS TONE DETECTION	TECHNOLOGY	TEST FEATURES	PACKAGE	COST	OTHER FEATURES
DIGITAL	•	•	NMOS	ALB	28-PIN CERAMIC DIP, PLASTIC DIP, PLCC	$13.35 (100)	ON-CHIP ADC AND DAC
DIGITAL	•	•	NMOS	ALB	28-PIN PLASTIC DIP, CERAMIC DIP, PLCC	$12.80 (100)	ON-CHIP ADC AND DAC. 150-BPS BACK CHANNEL. LEASED LINE AND TELEX COMPATIBLE
DIGITAL	•	•	CMOS	ALB DLB	44-PIN PLCC, PLASTIC DIP	$36 (100)	SELECTABLE ON-CHIP LINE EQUALIZER
DIGITAL	•	•	NMOS	ALB	28-PIN CERAMIC DIP, PLASTIC DIP, PLCC	$17.60 (100)	150-BPS BACK CHANNEL
SCF	•	•	HYBRID	ALB DLB	2.54×3.74-IN. MODULE	$245 (100)	FCC REGISTERED
SCF	•	•	HYBRID	ALB DLB	2.54×6.60-IN. MODULE	$395 (100)	MEMORY-EXPANSION PORT TO STORE 52 PHONE NUMBERS; FCC REGISTERED
SCF	•		HYBRID	ALB DLB	2.54×3.74-IN. MODULE	$179 (100)	FCC REGISTERED
DIGITAL AND SCF	•	•	HYBRID	ALB DLB	2.54×3.74-IN. MODULE	$390 (100)	FCC REGISTERED
SCF	•	•	HYBRID	ALB DLB	2.54×3.74-IN. MODULE	$265 (100)	FCC REGISTERED
SCF	•	•	CMOS	ALB	20-PIN CERAMIC DIP, PLASTIC DIP	$3.46 (100)	
SCF	•	•	CMOS	ALB, DLB EYE PATTERN	28-PIN CERAMIC DIP, PLASTIC DIP	$11.44 (100)	DEDICATED MODEM CONTROLLER AVAILABLE (XR-2131); COST AS LOOP-DEMODULATOR

Table continued on pg 124

REPRESENTATIVE MANUFACTURERS OF SINGLE-MODEM ICs *(Continued)*

COMPANY	DEVICE	STANDARDS: BELL 103	BELL 202	BELL 212A	CCITT V.21	CCITT V.22	CCITT V.22BIS	CCITT V.23	POWER SUPPLIES	POWER DISSIPATION	UART	DTMF	DUPLEXER	DAA
GE SOLID STATE	CD22212E	•		•					12V	180 mW		•		
	CD2223E	•						•	4.5 TO 13V	10 mW AT 5V 60 mW AT 12V				
MICRO POWER SYSTEMS	MP8512	•		•	•	•			5V –5V	240 mW	•	•	•	
NATIONAL SEMICONDUCTOR	UA212AT			•					5V –5V	35 mW		•		
	UAV22					•			5V –5V	40 mW		•		
ROCKWELL INTERNATIONAL	R24MFX MONOFAX				•				5V 12V –12V	1W				
	R48MFX MONOFAX				•				5V 12V –12V	1W				
SGS-THOMSON MICRO-ELECTRONICS	TSG7515	•		•		•			5V –5V	50 mW				
SIERRA SEMICONDUCTOR	SC11004	•		•		•			5V –5V	150 mW		•	•	
	SC11006	•		•	•	•	•		5V –5V	175 mW		•	•	
	SC11014	•		•	•	•			5V –5V	150 mW		•	•	
	SC11015	•		•	•	•			5V –5V	150 mW		•	•	
	SC11016	•		•	•	•			5V	70 mW		•	•	
SILICON SYSTEMS	K212	•		•					5V, 12V (2 VERSIONS)	30 mW AT 5V 180 mW AT 12V		•		
	K221				•	•			5V, 12V (2 VERSIONS)	30 mW AT 5V 180 mW AT 12V		•		
	K222	•		•	•	•			5V, 12V (2 VERSIONS)	30 mW AT 5V 180 mW AT 12V		•		
	K224	•		•	•	•	•		5V, 12V (2 VERSIONS)	100 mW AT 5V 360 mW AT 12V		•		
	K322					•		•	5V, 12V (2 VERSIONS)	30 mW AT 5V 180 mW AT 12V		•		
	K324				•	•	•	•	5V, 12V (2 VERSIONS)	120 mW AT 5V		•		
VLSI TECHNOLOGY	VL7C412			•	•	•			5V	70 mW		•	•	
	VL7C312			•	•	•			5V –5V	150 mW		•	•	
	VL7C212			•	•	•			5V –5V	150 mW		•	•	
	VL7224A	•		•	•	•	•		5V –5V	—		•	•	
XECOM	XE1212	•		•	•	•			5V –5V	400 mW	•	•	•	•
	XE1214	•		•	•	•			5V –5V	1W		•	•	•
	XE2400	•		•	•	•	•		5V –5V	1W		•	•	•

NOTES: 1. ALB = ANALOG LOOP BACK; DLB = DIGITAL LOOP BACK.
2. PLCC = PLASTIC LEADED CHIP CARRIER.
3. SCF = SWITCHED CAPACITOR FILTER.

FILTER TYPES	AGC	CALL-PROGRESS TONE DETECTION	TECHNOLOGY	TEST FEATURES	PACKAGE	COST	OTHER FEATURES
SCF	•	•	CMOS	ALB DLB	22-PIN DIP, 28-PIN PLCC	$16.50 (100)	PIN AND SOFTWARE COMPATIBLE WITH SSI'S K221, K222, AND K224 MODEM ICs
SCF			CMOS	INTERNAL LOOP-BACK TEST	16-PIN DIP	$6.19 (100)	DIGITAL DEMODULATOR
DIGITAL AND SCF	•	•	CMOS	ALB DLB	40-PIN DIP	$15 (100)	
DIGITAL		•	CMOS	ALB DLB	28-PIN DIP, SMD	$18 (100)	
DIGITAL		•	CMOS	ALB DLB	28-PIN DIP, PLCC	$18 (100)	
SCF AND DIGITAL	•	•	CMOS (ANALOG) NMOS (DIGITAL)	EQM (EYE QUALITY MODEM)	64-PIN QUAD-IN-LINE PACKAGE	$49 (1000)	DSP CHIP CONFORMS TO V.27TER 2400-BPS OPERATION; ADAPTIVE EQUALIZER
SCF AND DIGITAL	•	•	CMOS (ANALOG) NMOS (DIGITAL)	EQM (EYE QUALITY MODEM)	64-PIN QUAD-IN-LINE PACKAGE	$60 (1000)	CONFORMS TO V.27TER 4800-BPS OPERATION; DSP CHIP
SCF	•	•	CMOS	ALB DLB	28-PIN DIP	$20 (100)	DIGITAL PLL DEMODULATOR GENERATES 1800-Hz GUARD TONE ONLY
SCF	•	•	CMOS	ALB DLB	24-PIN DIP, 28-PIN PLCC	$18.20 (100)	OPERATES WITH SC11007/008/017 DEDICATED CONTROLLERS
SCF	•	•	CMOS	ALB DLB	28-PIN DIP, PLCC	$35 (100)	ADAPTIVE EQUALIZATION AND DESCRAMBLING DONE IN SC11009/010/011 CONTROLLER
SCF	•	•	CMOS	ALB DLB	24-PIN DIP, 28-PIN PLCC	$21 (100)	DEDICATED CONTROLLER; (SC11007/008/017)
SCF	•	•	CMOS	ALB DLB	24-PIN DIP, 28-PIN PLCC	$23 (100)	PROGRAMMABLE GAIN AMPLIFIER, USES DEDICATED CONTROLLER
SCF	•	•	CMOS	ALB DLB	24-PIN DIP, 28-PIN PLCC	$25.90 (100)	STANDBY POWER MODE; DEDICATED CONTROLLER (SC11027/028)
SCF	•	•	CMOS	ALB, DLB TEST PATTERN	22-PIN DIP, 28-PIN DIP, 28-PIN PLCC	$21 TO $24 (100)	COMPROMISE EQUALIZER; PIN COMPATIBLE WITH K SERIES
SCF	•	•	CMOS	ALB DLB	22-PIN DIP, 28-PIN DIP, 28-PIN PLCC	$24 TO $25 (100)	PIN COMPATIBLE WITH K SERIES
SCF	•	•	CMOS	ALB DLB	22-PIN DIP, 28-PIN DIP, 28-PIN PLCC	$29 TO $34 (100)	PIN COMPATIBLE WITH K SERIES
SCF	•	•	CMOS	ALB DLB	22-PIN DIP, 28-PIN DIP, 28-PIN PLCC	$65 TO $70 (100)	COMPROMISE AND ADAPTIVE EQUALIZER COMPATIBLE WITH K SERIES
SCF	•	•	CMOS	ALB DLB	22-PIN DIP, 28-PIN DIP, 28-PIN PLCC		75-BPS BACK CHANNEL COMPATIBLE WITH K SERIES
SCF	•	•	CMOS	ALB DLB	22-PIN DIP, 28-PIN DIP, 28-PIN PLCC		COMPROMISE AND ADAPTIVE EQUALIZERS; COMPATIBLE WITH K SERIES
SCF	•	•	CMOS	ALB DLB	24-PIN DIP, 28-PIN PLCC	$9 (100,000)	DIRECT REPLACEMENT FOR SIERRA SC11016; COMPROMISE EQUALIZER
SCF	•	•	CMOS	ALB DLB	24-PIN DIP, 28-PIN PLCC	$9.50 (100,000)	DIRECTLY REPLACES SC11015; PROGRAMMABLE GAIN RECEIVER
SCF	•	•	CMOS	ALB DLB	24-PIN DIP, 28-PIN PLCC	$9 (100,000)	DIRECTLY REPLACES SC11004 AND SC11014; AUDIO OUTPUT PORT
SCF	•	•	CMOS	ALB DLB	28-PIN DIP, PLCC	$13 (100,000)	ADAPTIVE EQUALIZATION IS PERFORMED IN DEDICATED CONTROLLER (VL7C235/245)
SCF	•	•	HYBRID	ALB DLB	40-PIN 2.28×1.00×0.50-IN. PACKAGE	$116 (100)	FCC REGISTERED
SCF	•	•	HYBRID	ALB DLB	40-PIN 2.28×1.00×0.5-IN. PACKAGE	$116 (100)	FCC REGISTERED
DIGITAL	•	•	HYBRID	ALB DLB	40-PIN 2.75×1.38×0.625-IN. PACKAGE	$269 (100)	FCC REGISTERED

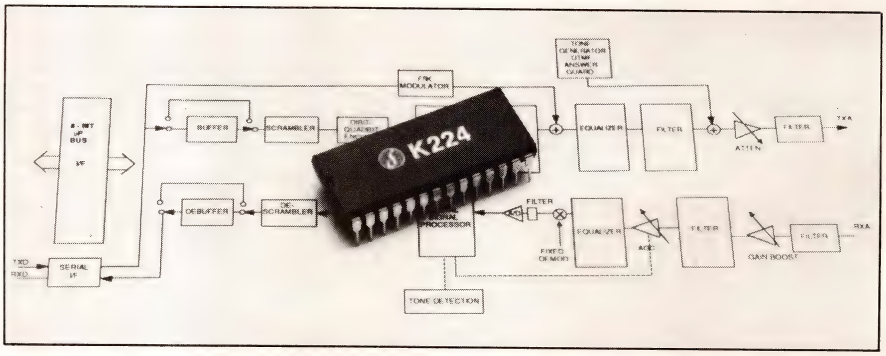
If you're willing to spend the money on a hybrid module, you'll get an FCC-registered DAA.

tas loop coherently demodulates the phase-encoded data in the receiver. The XR-2130 has call-progress detection, DTMF dialing, and analog, digital (local and remote) loopback test modes. With the addition of another chip (the XR-2100), it can support CCITT V.21 0- to 300-bps operation. The device comes in a 28-pin DIP.

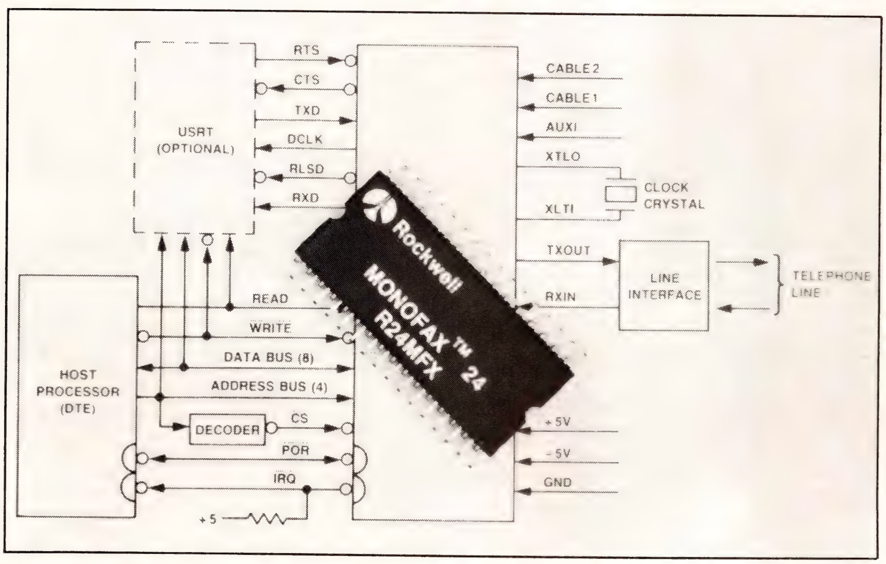
The TSG7515 chip from SGS-Thomson also conforms to Bell 212A and 103 and CCITT V.22 (A, B) modem specifications. The filters for the transmit and receive functions as well as for call-progress detection are built with switched-capacitor filters. The chip generates all of the necessary modulation and answer tones along with the 1800-Hz guard tone for V.22 operation. It does not have a DTMF generator or a 4- to 2-wire hybrid on chip, however, which means that you need additional external components to implement these functions. The chip uses a digital phase lock loop (PLL) in the quad-PSK demodulator.

Full-duplex, 2400-bps operation is also possible

Single-IC modems are also moving into the 2400-bps marketplace. The CCITT V.22bis specification, which establishes the requirements for full-duplex operation, stipulates that data be encoded into quad bits. This encoded data performs amplitude and phase modulation of the carrier frequency, using QAM, resulting in 16 constellation points. Because this operation requires a complex modulation and demodulation process, the V.22bis specification calls for adaptive equalization to compensate for transmission-line distortions and to reduce intersymbol interference. The SSI K224 modem, discussed previously, performs these functions on a single chip.



The K224 single-chip modem contains *all of the modem functions to operate at 1200 and 2400 bps. This K Series member, available from Silicon Systems, is plug compatible with all other K Series devices.*



The R24MFX Monofax modem consists of two chips *housed in a quad-in-line package. Manufactured by Rockwell, the IC is optimized for compact Group 3 facsimile machines.*

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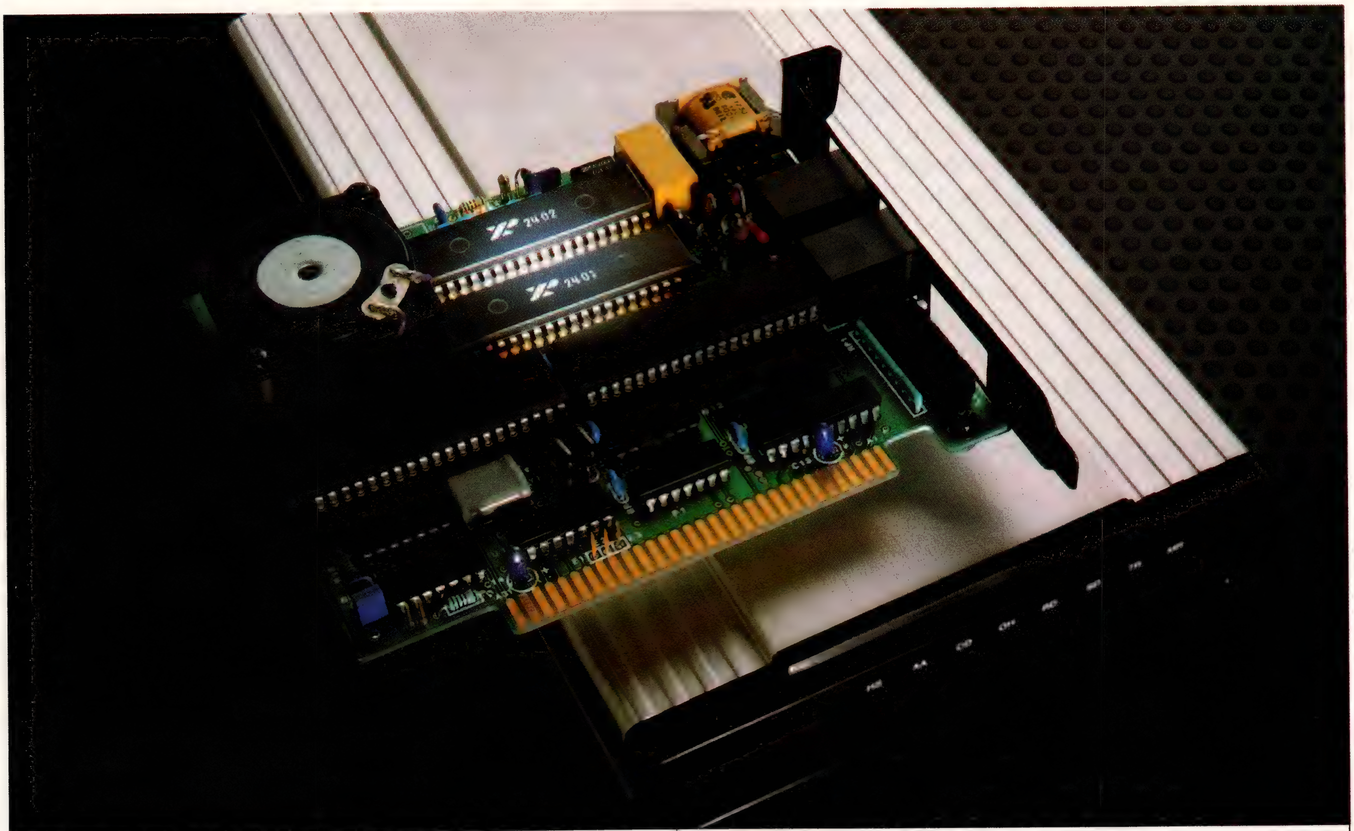

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Some manufacturers have allotted some modem tasks to a dedicated controller because the modem requires a controller for housekeeping tasks anyway.

Because it is possible to perform adaptive equalization and some modem tasks using digital techniques, certain manufacturers have allotted these functions to an external controller; a controller is necessary for housekeeping tasks, in any case (eg, handshake protocols and mode control). Both Sierra Semiconductor and VLSI Technology Inc have taken this approach. The companies' 1200-bps single-chip modems have all of their modem functions on one chip (including the 4- to 2-wire hybrid), but their 2400-bps products have some of their modem functions handled by the external controller.

Sierra Semiconductor's SC11006 chip contains the functions for 2400-bps QAM, 1200-bps quad PSK (QPSK), and 0- to 300-bps operation. A 4- to 2-wire hybrid is also included. The chip is compatible with Bell 212A and 103, and CCITT V.21, V.22, and V.22bis standards. The on-chip transmitter includes the data encoder; a quadrature modulator; high-band and low-band filters and compromise equalizers; a programmable attenuator for transmit-level adjustment; and DTMF, guard-tone, and answer-tone generators. The

Glossary of modem terminology

The following is a brief glossary of some specialized modem-terminology phrases.

Analog loop back (ALB)—A diagnostic mode whereby the analog output of the transmitter connects to the analog input of the receiver. This mode allows the local receiver to demodulate the data modulated by the local transceiver.

Answer tone—An answering modem, after automatically answering a call, transmits an answer tone back to the originating modem, which indicates to the originating modem's system that the remote modem has answered the call.

Asynchronous transmission—A data-tranmission scheme that handles data without clock synchronization. It consists of a character code comprising a start bit, five to nine data bits, a parity bit, and one or two stop bits.

Back channel—A low-data-rate channel used on half-duplex modems to allow small amounts of data to be received or transmitted in the opposite direction of the main-channel data.

Baud rate—A unit of signaling speed equal to the number of modulations per second. In FSK modulation, it is equal to the bps rate. In QPSK, it is half the bit rate because the data is encoded in dibits.

Bit rate (bps)—Number of bits transmitted per second.

Data-access arrangement (DAA)—Protective circuitry that the FCC requires so that the user is protected from harsh telephone environments, and so that the network is protected from customer-equipment malfunction.

Digital loop back (DLB)—A diagnostic mode whereby received digital data at a remote modem is connected to the transmit digital input for retransmission back to the originating modem. Because an analog medium, such as the PSTN, is used in the test, both the remote modem and the medium are under scrutiny.

Dual tone multiple frequency (DTMF)—Two distinct telephone signaling tones used for dialing.

Duplexer (4- to 2-wire hybrid)—Circuit that matches the 4-wire modem signal to the 2-wire telephone network.

Full duplex—Simultaneous data transmission by two modems at the same speed in different directions.

Guard tones—Tones that are specified in some CCITT standards and which must be transmitted when using certain international telephone exchanges.

Half duplex—Data transmission between two modems that takes place in only one direction at a time. The line must be "turned around" to allow data transmission in the opposite direction. In some cases, a back channel is included, which permits a low-data-rate channel in the opposite direction.

Hybrid, 4- to 2-wire—See duplexer.

On/off hook switch—Switch in the DAA that indicates that the customer is connected to the telephone network. When the switch is in its off-hook state, current flows from the telephone central office through the customer's equipment.

Progress tones—Signaling tones that the central telephone office provides to indicate network conditions to the customer. Some examples are dial tone, ringback tone, and busy signal.

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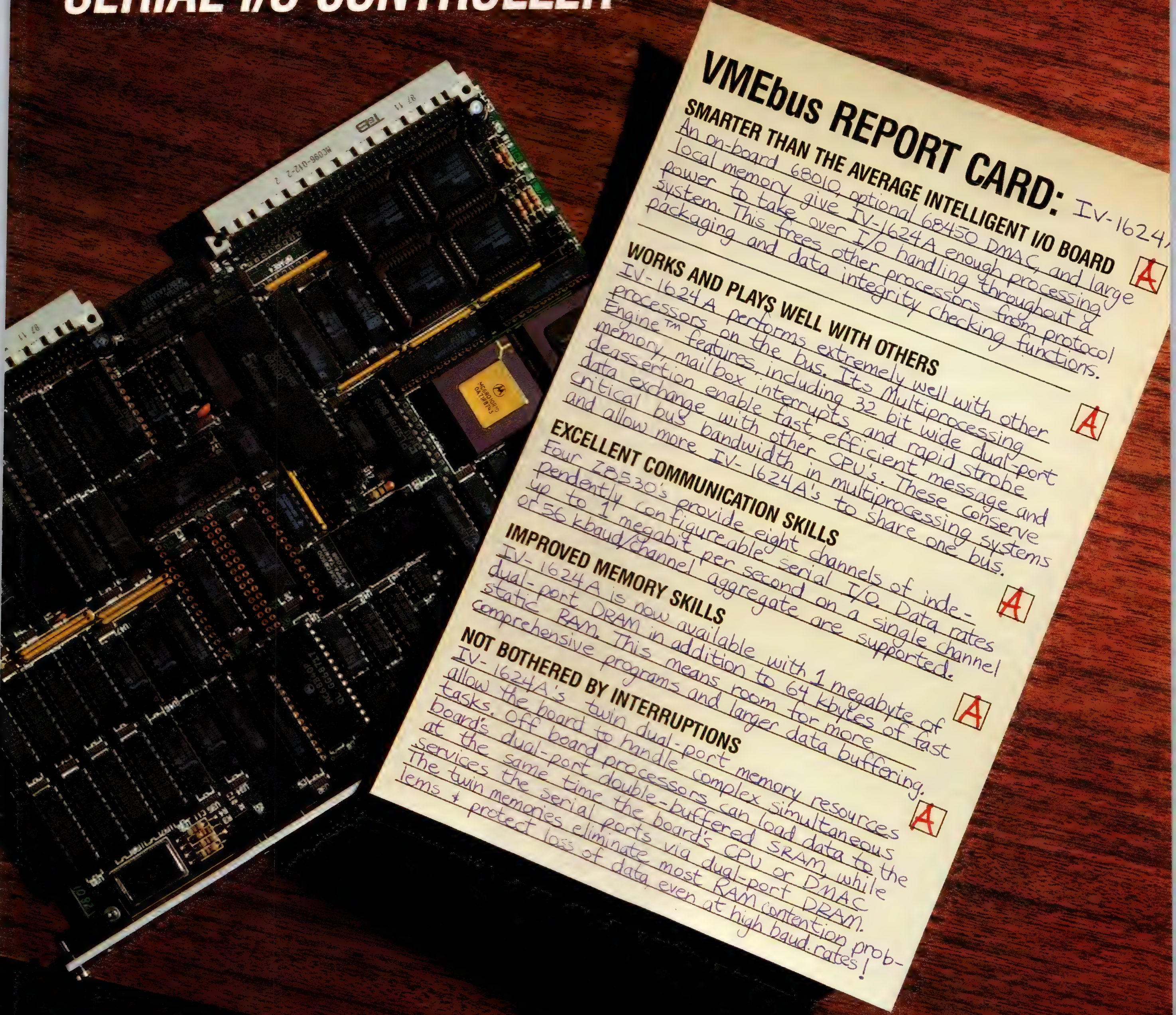

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If you have to have your own DAA qualified, you should retain the services of a modem consultant.

on-chip receiver has a 64-step programmable-gain amplifier, a Hilbert transformer, a quadrature demodulator, an 8-bit A/D converter, an audio output port, control and status registers, and an 8-bit μP interface with multiplexed address and data lines. The chip comes in either a 28-pin DIP or PLCC.

The external controller can be either a dedicated controller such as a Sierra SC11009 (for parallel bus applications) or SC11010 (for RS-232C applications) or a general-purpose μcontroller such as Intel's 8096. The Sierra dedicated controller contains the complete Hayes AT command set and performs adaptive equalization, carrier phase recovery, data decoding, and descrambling on 8-bit samples from the SC11006 chip. After the samples are processed, the controller writes the data back to the modem chip to perform synchronous-to-asynchronous conversion, if required.

VLSI Technology's VL7C224A 2400-bps modem chip also conforms to CCITT V.22bis as well as CCITT V.22 and V.21 and Bell 212A and 103 standards. And, like its Sierra counterpart, it relies on an external controller to perform adaptive equalization, carrier phase recovery, data decoding, and descrambling. The chip interfaces with either an 8096 μcontroller or one of the company's dedicated controllers such as the VL7C225, 235, or 245, which contain the Hayes AT command set in firmware. The device contains DTMF and guard-tone generators, call-progress detectors, and an on-chip 4- to 2-wire hybrid. It provides analog, digital, and remote digital loopback test features along with a programmable audio output.

To a purist, a hybrid modem may not be a single-IC modem because a hybrid module contains many chips. However, for an OEM designer who needs a single-package solution, the difference may not matter. And, because these modules contain the necessary 4- to 2-wire hybrid and DAA unit, the real estate required to build a complete modem is comparable to that of the single-IC modems described thus far.

The initial cost of a hybrid module is considerably greater than than that of a single-IC design, but the inclusion of an FCC-registered DAA can enable you to get your product to market fast. Purchasers of the aforementioned single-IC modems, who have to qualify their own DAAs, would be wise to retain the services of a modem consultant. The time to obtain FCC approval

Manufacturers of single-IC modems

For more information on single-IC modems such as the ones discussed in this article, contact the following manufacturers directly, circle the appropriate numbers on the Information Retrieval Service card, or use EDN's Express Request service.

Advanced Micro Devices Inc
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TWX 910-339-9280
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Micro Power Systems
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National Semiconductor Corp
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TLX 346353
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Rockwell International Corp
Semiconductor Products Div
Box C
Newport Beach, CA 92658
(714) 833-4700
Circle No 656

SGS-Thomson Microelectronics Inc
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Carrollton, TX 75006
(214) 466-6000
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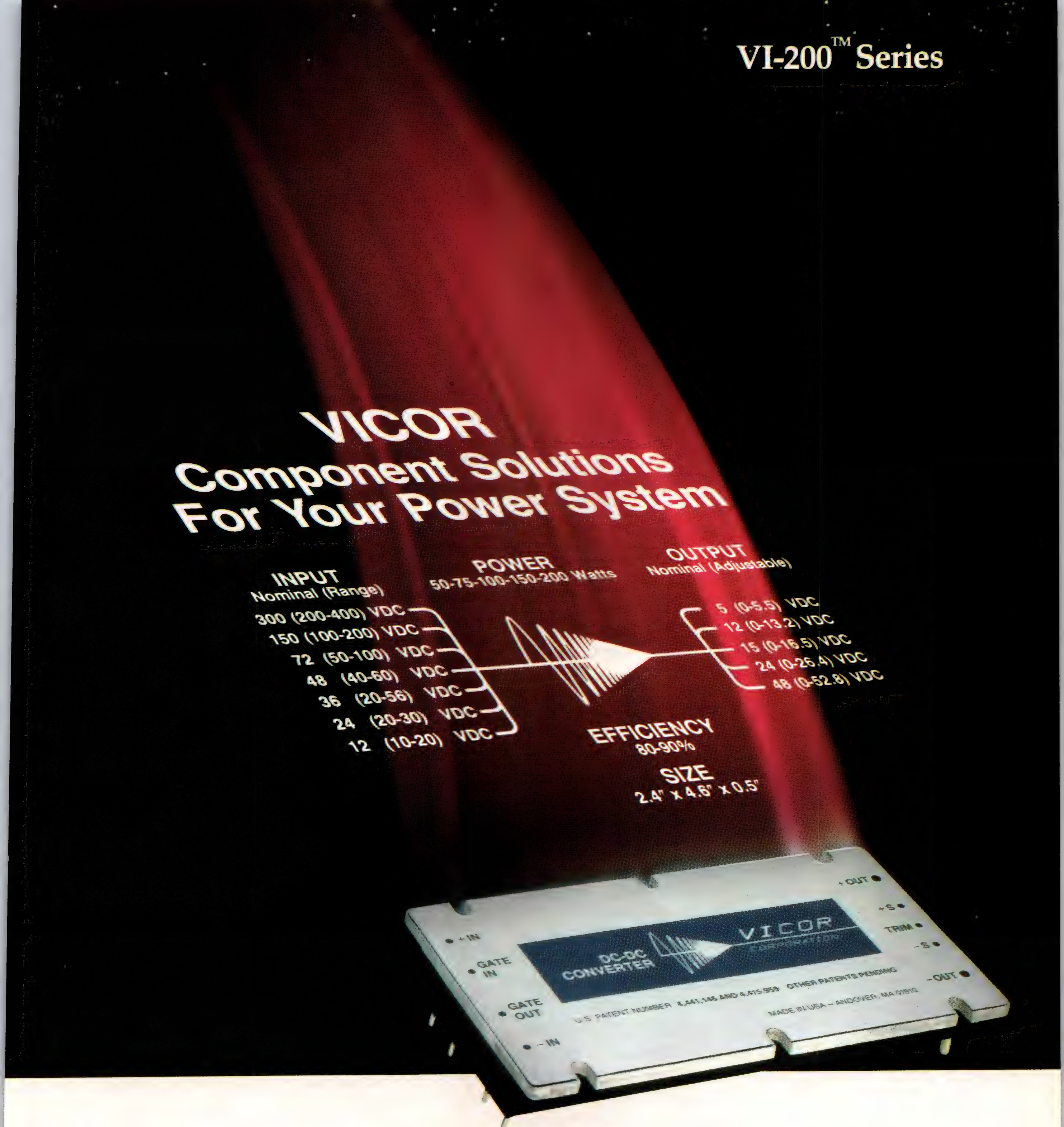

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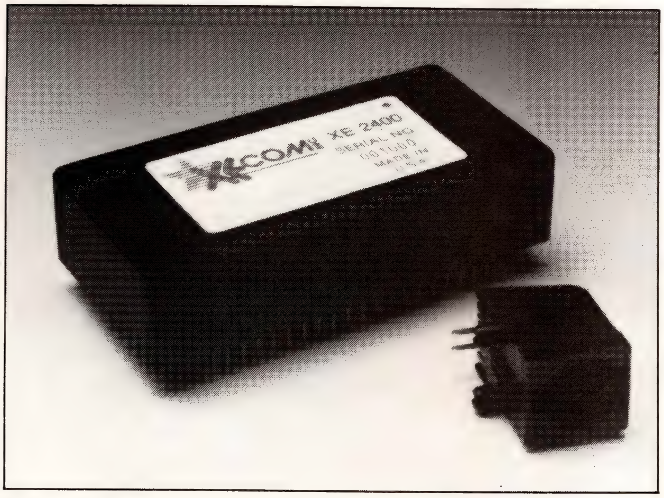
Different manufacturers have approached the single-IC-modem market from various directions, and therefore it's difficult to define a single-IC modem.



***Hybrid modules, such as the XE2400** from Xecom, have built-in 2- to 4-wire hybrids and FCC-registered DAAs. Hybrid modules have the advantage of being quicker to get to market.*

is typically 90 days, and, if the FCC rejects your design, you will have to modify it and start all over again—at the end of the queue. A qualified consultant, however, will test the design to FCC specifications and suggest modifications before submitting it to the FCC for approval. The approximate $2500 fee includes the services of the consultant and FCC charges.

The CH1780 hybrid module from Cermetek conforms to CCITT V.22bis and V.22 and Bell 212A and 103 specifications and therefore operates at 2400, 1200, and 0 to 300 bps, respectively. It measures 2.54×3.74×.75 in. and has 44 pins, which you can directly solder or place in a socket. Like all hybrid modules, the CH1780 contains the 4- to 2-wire hybrid and a built-in FCC Part 68-registered DAA with an FCC registration number and Ringer Equivalence Number (REN). The module responds to the Hayes AT command set, allowing it to answer and initiate calls and execute diagnostic tests. Because the module is configured for serial communications, a UART is required to interface with a host. The host controls the modem by sending serial ASCII command sequences.

Another hybrid module is Xecom's XE2400, which measures 2.75×1.38×.625 in. and has 40 pins. The device conforms to CCITT V.22bis, V.22, and V.21, and Bell 212A and 103 specifications. It uses the Hayes AT command set, interfacing with the host through a serial TTL interface; a series of ASCII commands provides control. The XE2400 supports analog and digital loopback tests.

Rockwell International chooses to put more than one chip on a single substrate and call it a single-package modem. The R48MFX Monofax facsimile modem comprises two chips packaged in a 64-pin quad-in-line package. Optimized for use in compact Group 3 facsimile machines, it supports CCITT V.27ter 4800- and 2400-bps half-duplex modes as well as the CCITT V.21 spec for 0- to 300-bps protocol communications. The unit includes adaptive equalization, can diagnostically determine line quality, and has two DTE interfaces (a parallel μP bus and an RS-232C serial port). It also contains DTMF generators.

Different manufacturers have approached the single-IC-modem market from various directions, and therefore it is difficult to put bounds on the devices to include in a report such as this. All single-IC modems, however—regardless of definition—require a controller. Keeping this in mind, this report has limited its coverage to single-IC modems that have all the modem functions performed by either a single-package device or a single device and a controller. If you have the real estate for an additional IC, however, many manufacturers, such as Intel, Exar, and Gould, sell 2400-bps modems with the modem functions split between two ICs. These chip sets consists of an IC for the analog front-end section followed by an IC that performs the remaining modem tasks. The two chips must then interface with a controller to function as a modem. **EDN**

Reference

1. *The Modem and Modem ICs Market*, Electronic Trend Publications, Saratoga, CA, 1987. The reports sells for approximately $1000.

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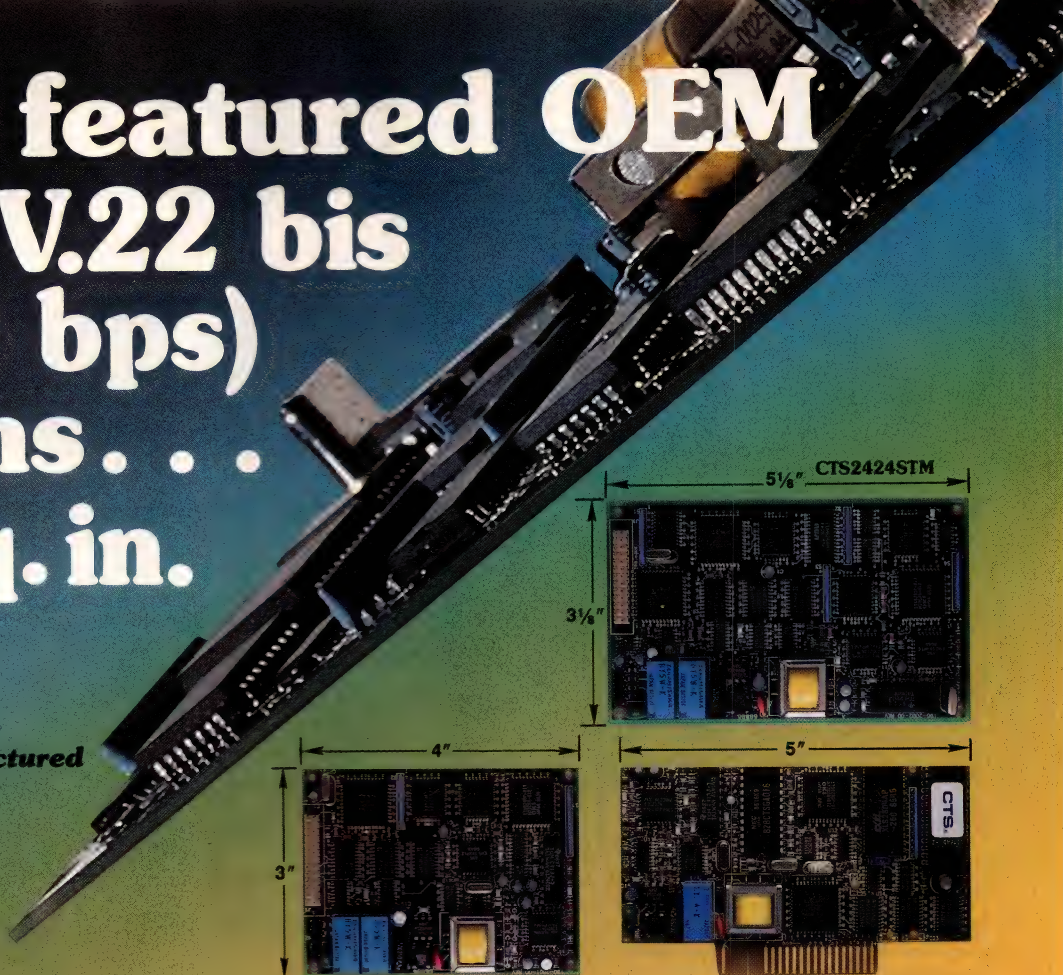

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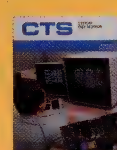

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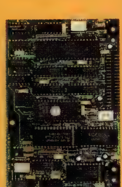

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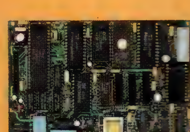

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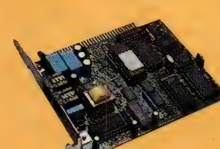

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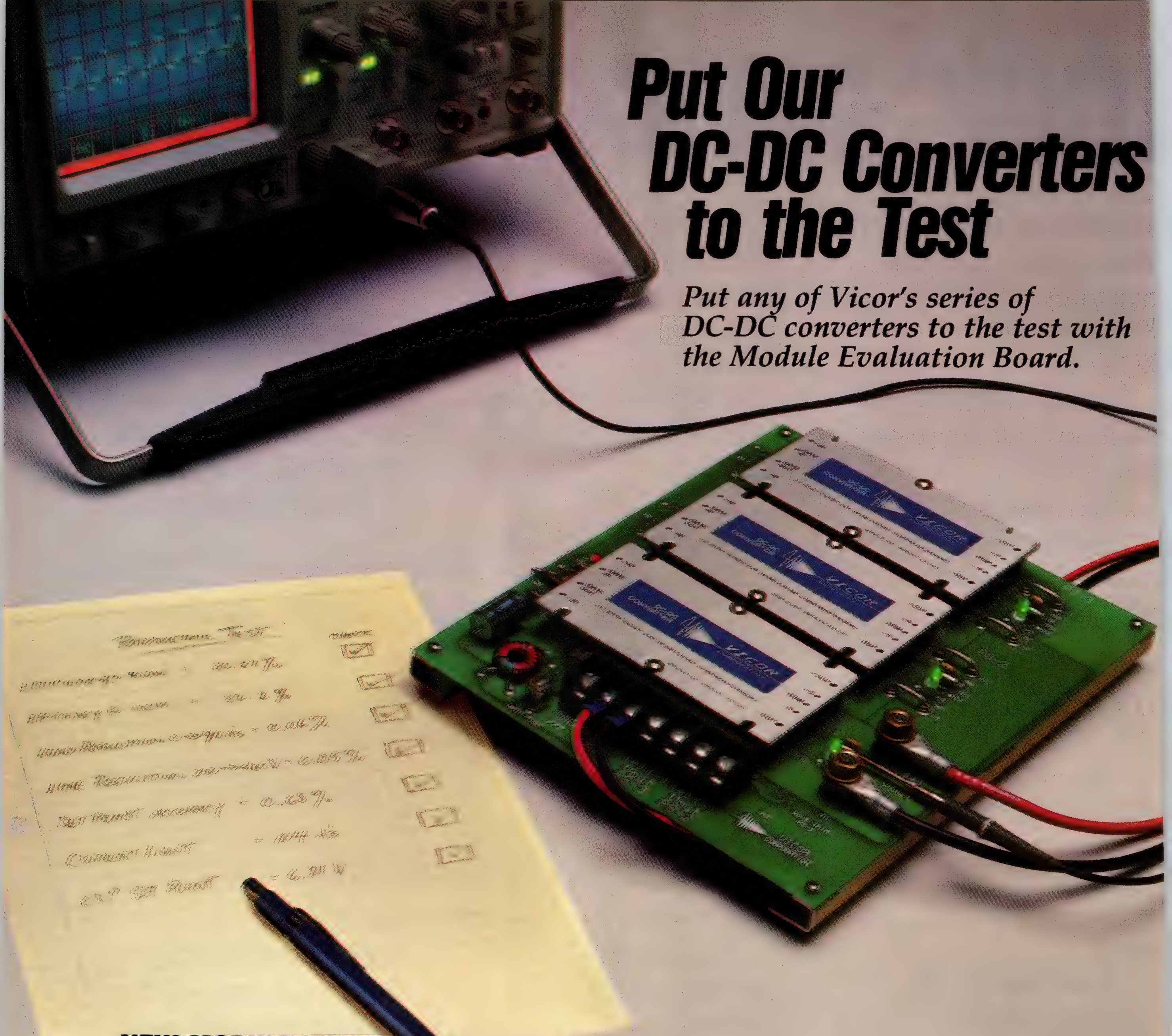

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X2864BM	8192 x 8	32	120, 150, 180
X2864HM	8192 x 8	32	90
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X28C256M	32768 x 8	64	250, 300, 350
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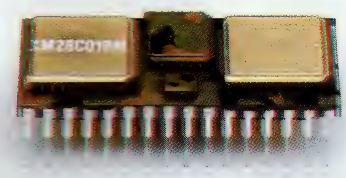

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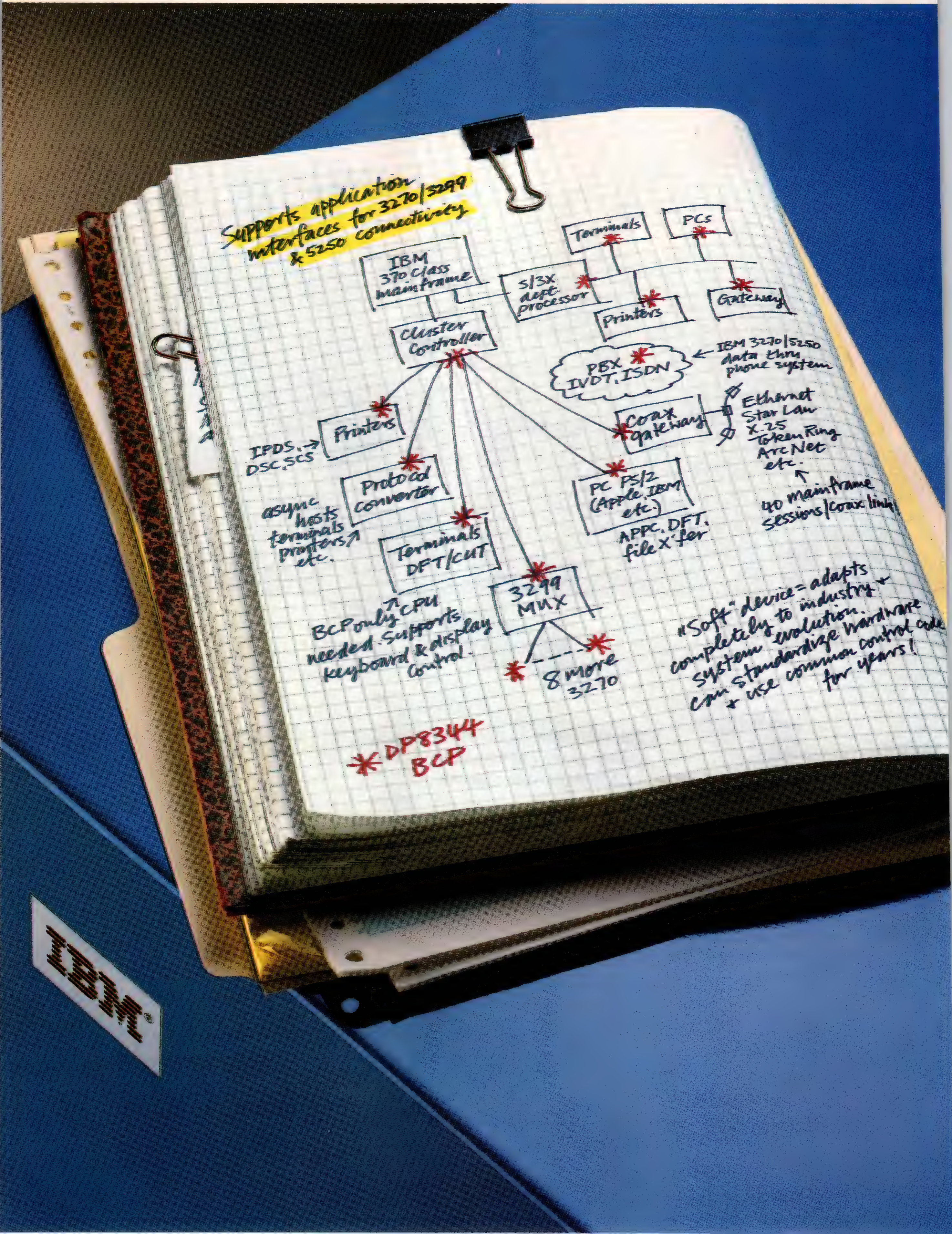

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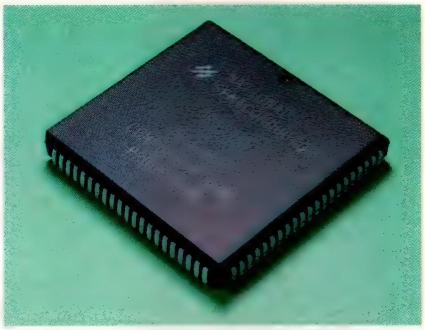

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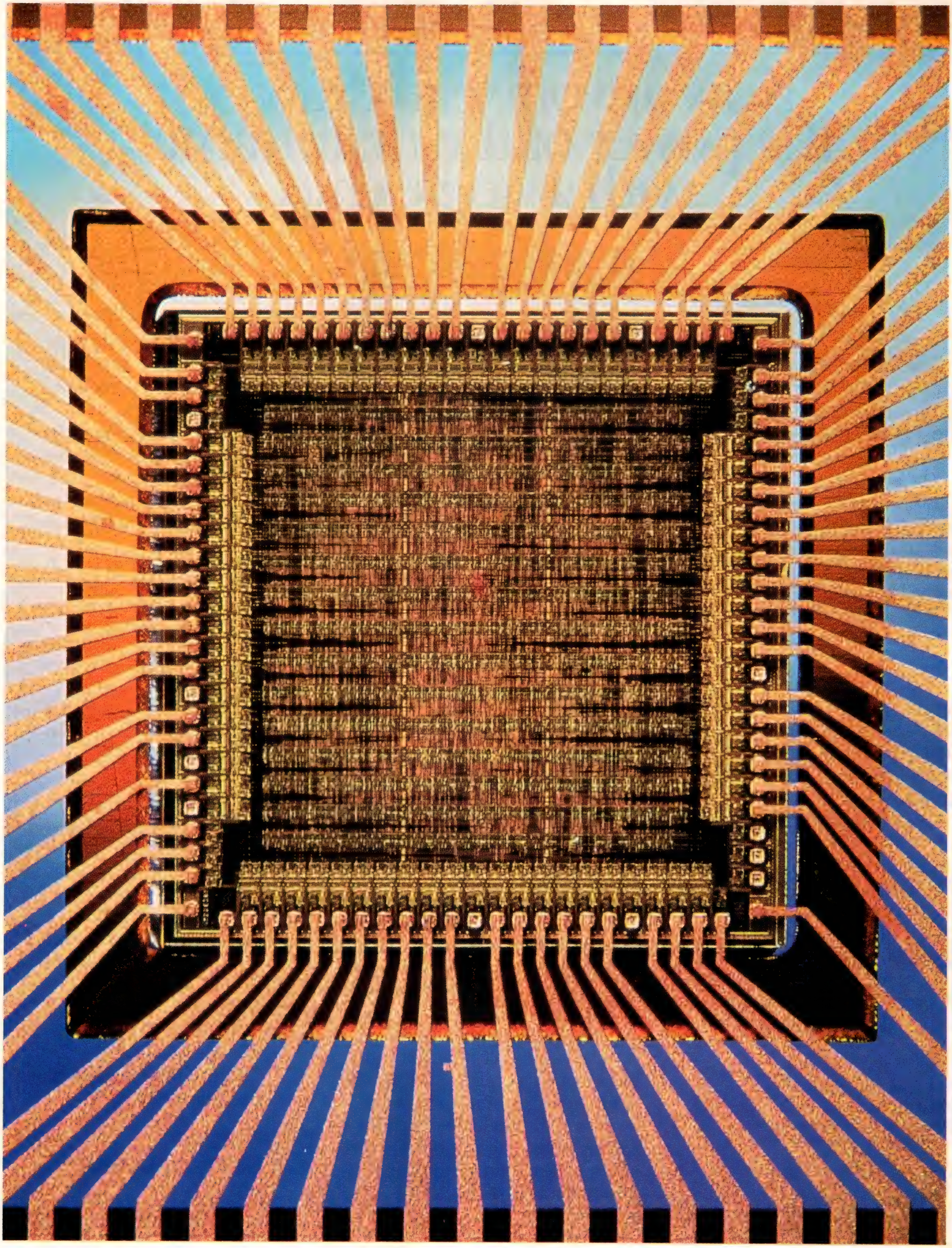


Advanced packaging will play a key role *in the creation of devices and systems in the 1990s. This 84-lead IC resides in a National Semiconductor TapePak package and occupies only 0.36 in*^{2} *of pc-board space. You can use conventional surface-mount techniques to attach the device to a pc board.*

PART FOUR
DECADE 90
The future of system design

New package technology supports soaring IC and system complexity

The ubiquitous DIP and board-and-backplane technologies have dominated electronic packaging for the last 25 years. However, the growing sophistication of devices and systems signals the decline of such packaging schemes and heralds the arrival of more-advanced techniques for systems designed in the 1990s.

Steven H Leibson, *Regional Editor*

Customers and end users expect electronic systems to become smaller, faster, and more powerful every year; such progress is the hallmark of our industry. The relentless increases in semiconductor integration have played—and will continue to play—a large part in this process, but the next decade's system engineers will also rely on advanced packaging techniques to achieve those size, cost, and performance goals.

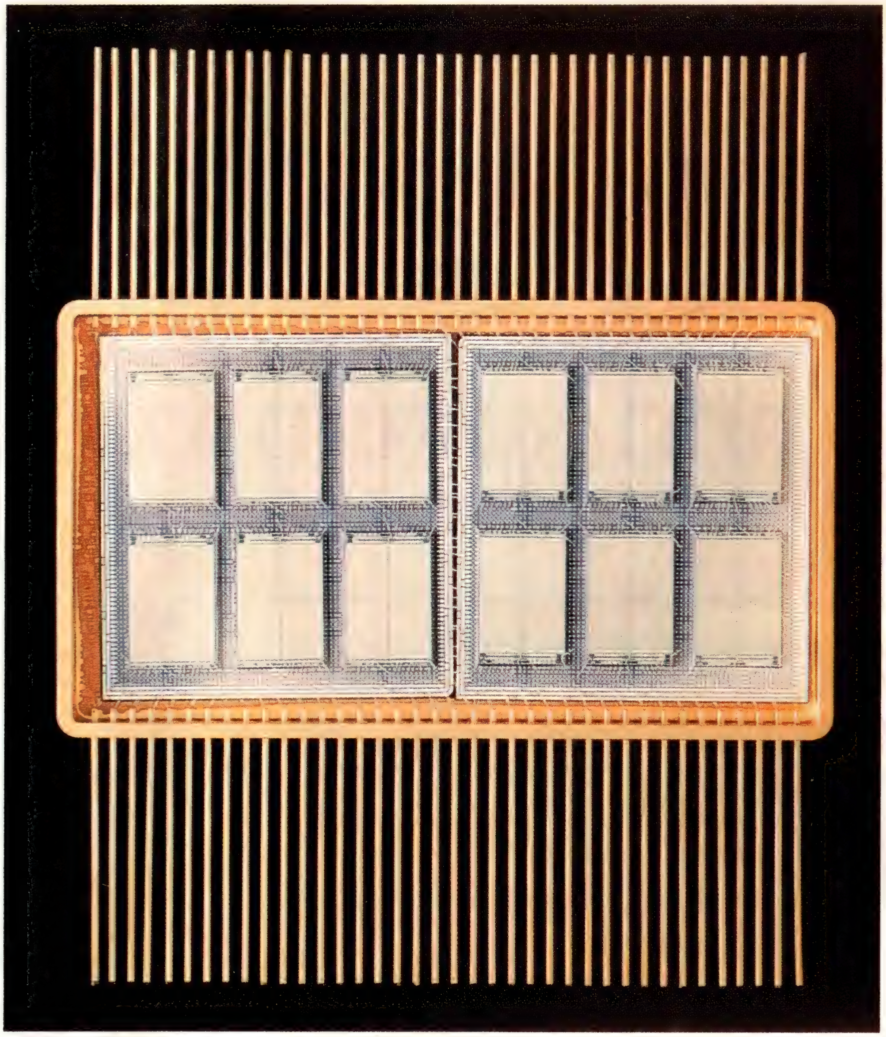
Although IC densities increased by six orders of magnitude over the last 25 years, packaging and interconnect technology made only modest gains during that same time. Indeed, because device and system packaging presented few problems for the simpler designs and slower signal rates of the past, packaging technology didn't receive the same attention that IC design did, so it didn't advance in tandem with IC technology. DIPs, for example, went from 14 to only 64 leads, and most engineers continued to use fairly ancient board-and-backplane technologies when designing multicard systems.

These old packaging and interconnection schemes are limiting the speed and complexity of today's advanced systems. Emerging packaging technologies, however, promise to overcome the existing performance barriers by improving electrical characteristics and costs while shrinking board-space requirements. They simply do more with less: They carry higher-frequency signals and handle more interconnections than earlier packaging technologies did, yet use less material.

Packaging issues are now critical to advanced system design, because highly sophisticated electronic systems require increasingly complex interconnection schemes. According to Rent's Rule, an empirical model of system interconnection developed in the 1960s **(Ref 1),** as chips become more and more complex, they require more leads or pins to connect with the rest of a system. Rent's Rule emphasizes something that engineers now take for granted—that soaring IC complexities demand ever-increasing amounts of interconnection circuitry.

Packaging and interconnect lack pizzazz

Unfortunately, many of the most publicized semiconductor projects dedicated to creating these future ICs don't devote the same level of engineering effort to packaging and interconnection issues that they do to



Two silicon circuit boards in a hybrid package *hold twelve 32k×8-bit static RAM chips, creating a 3M-bit, 65-nsec, cache-memory module. (Photo courtesy Mosaic Systems Inc)*

circuit design. According to Robert E Holmes, chief scientist for the Hybrid Components Operation at Tektronix (Beaverton, OR), major projects such as the US government's VHSIC (very-high-speed IC) and MMIC (monolithic microwave IC) programs and the Sematech consortium (in Austin, TX) put "millions of dollars into semiconductor research, but pennies into packaging." Holmes points out that companies wishing to develop new packaging technologies must conduct some basic research: They need to find new materials that solve existing power-dissipation, TCE (thermal coefficient of expansion), and interconnection problems. Funding for such research has been lacking, he says.

Though packaging may not enjoy the same amount of attention as semiconductors do, it's still making progress. For example, surface-mount technology (SMT) is currently forcing systems vendors to revamp their manufacturing processes. SMT replaces board stuffing, which is traditionally a manual process, with very high levels of automation. SMT also effects substantial system size reductions and speed increases. The diminutive SMT packages allow system engineers to shrink existing systems or pack more capabilities into an existing box. The shorter lead lengths of these SMT packages permit faster system operating speeds because they exhibit less resistance, capacitance, and inductance. In addition, the 50-mil lead pitch of SMT packages allows for higher lead counts than conventional through-hole DIPs do.

Because SMT manufacturing represents a major departure from traditional production techniques, US companies have been slow to adopt it. According to

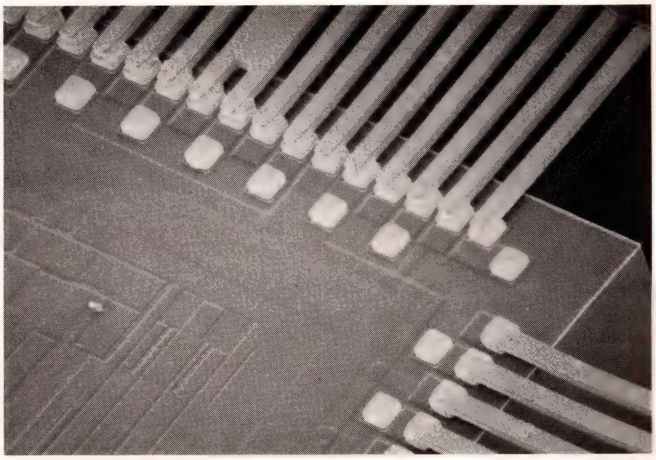


__Fig 1—TAB technology allows chip vendors__ to bring many more signals off an IC with connections that have lower impedance, more ruggedness, and more reliability than conventional wire bonds provide. In addition, TAB can accommodate ICs with closer pad spacing than wire-bond technology allows. (Photo courtesy Motorola Inc)

Diane Taylor and Donn Fischer, authors of the book *Surface Mount Technology: A Strategic Report*, 15% of the electronic equipment built in the US during 1985 incorporated SMT. The book predicts that the figure will grow to only 30% by 1990. For Japan, however, those figures are 30% and 50%, respectively.

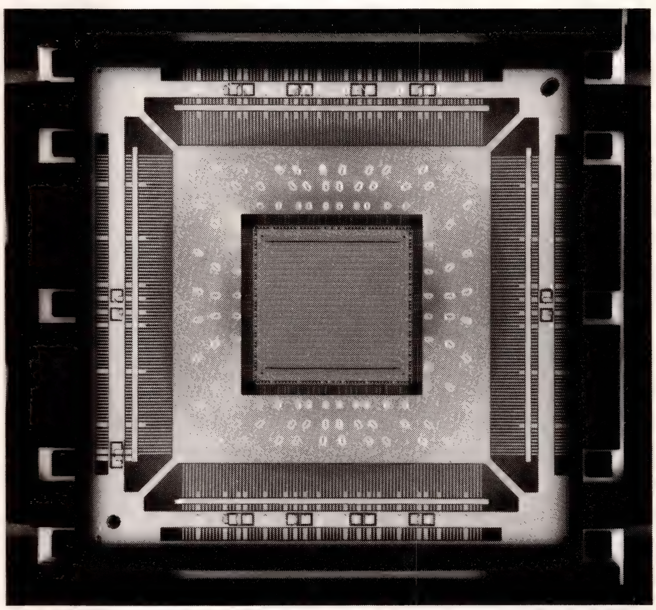
Several of the factors slowing the growth of SMT in the US are a general domestic shortage of SMDs, the incomplete availability of popular logic families in SMD packages, the substantial up-front capital needed for SMT manufacturing equipment, and engineers' inexperience with SMT design techniques. Despite those obstacles, the electronics industry will inevitably convert to SMT manufacturing on a worldwide basis during the 1990s, because by automating production, SMT will let companies produce higher-quality products at a lower cost.

Unfortunately, even today's SMT packages can't achieve the high lead counts forecast for the very dense chips of the 1990s. Currently, plastic leaded chip carriers (PLCCs) have no more than 124 leads, a capacity that falls far short of meeting those future needs. Some advanced ASICs available this year already require more than 500 leads. Even the pin-grid array (PGA)—an expensive and space-consuming package—can't accommodate such devices. To meet high lead-count requirements, packaging engineers are refining an existing package technology: tape-automated bonding (TAB).

Military projects have employed TAB as a high-reliability packaging scheme for more than a decade. TAB improves the reliability of an IC's interconnection by eliminating wire bonds and attaching a tape-based lead frame directly to the silicon die instead **(Fig 1)**. TAB's lead frames have more strength than individually applied, gold wire bonds.

TAB has the potential to become a low-cost packaging technology because gang-bonding equipment can attach high lead-count dies to TAB lead frames much faster than a wire bonder can stitch wires between a chip and a conventional lead frame. Most current TAB packaging schemes, however, employ relatively expensive multilayer film lead frames of copper and polyimide. They also require you to use special equipment for attaching the TAB package to substrates such as pc boards. Therefore, TAB has remained primarily a military technology.

Nevertheless, National Semiconductor (Santa Clara, CA) now uses TAB to construct a low-cost, commercial IC package. The company was investigating inexpensive, reliable, multichip packaging schemes for dynamic-RAM modules and started experimenting with chip-on-board and chip-on-tape approaches to reduce board-space requirements. As a result of this project, National Semiconductor's engineers developed the



__TAB packaging accommodates high lead-count devices__ such as this 360-lead IC. Currently, TAB handles as many as 500 leads per chip; that figure could reach 1000 during the next decade. (Photo courtesy Motorola Inc)

TABLE 1—WIRE-BOND VS TAB PACKAGING

	WIRE-BOND PACKAGING						TAB PACKAGING			
	40-LEAD DIP		44-LEAD PLCC		132-LEAD PQFP		40-LEAD TAPEPAK		132-LEAD TAPEPAK	
LEAD TYPE	LONG	SHORT	LONG	SHORT	LONG	SHORT	LONG	SHORT	LONG	SHORT
LEAD LENGTH (IN.)	0.99	0.13	0.20	0.15	0.38	0.26	0.12	0.06	0.31	0.23
RESISTANCE (mΩ)	125	123	98	98	102	101	3.6	2.2	11	8.2
INDUCTANCE (nH)	22	3.9	4.6	3.3	10	7.2	2.1	0.8	6.7	5.1
CAPACITANCE (pF)	0.68	0.12	0.12	0.16	0.21	0.15	0.04	0.02	0.11	0.08

NOTES:
PLCC=PLASTIC LEADED CHIP CARRIER
PQFP=PLASTIC QUAD FLAT PACK
INFORMATION COURTESY NATIONAL SEMICONDUCTOR

TapePak, a TAB packaging technology that combines a single-layer, all-copper lead frame with a molded plastic body and guard ring.

TAB drops lead impedances

TapePak improves connectivity to a die by doing more with less—it replaces bond wires with a short lead frame, greatly reducing lead impedances when compared with similar packages based on wire bonds (**Table 1**). TapePak devices require minimal pc-board space because the molded plastic body is just slightly larger than the die it encloses. National Semiconductor currently offers linear, bipolar devices in TapePak packages, and also plans to put its HPC family of μCs, disk-controller chips, and μP support ICs in TapePak packages. The company has defined four TapePak body styles for ICs with 40 to 360 leads and has obtained JEDEC approval for its 40-, 52-, 68-, and 84-lead designs.

The plastic TapePak body protects the die, unlike military TAB designs, which leave the chip naked and rely on more-expensive ceramic or metal packages for physical ruggedness. TapePak's guard ring protects the IC's delicate leads until the package is attached to a substrate. The ring also delineates a region between the TapePak body and the guard ring, allowing the fine-pitched leads to fan out to test points on 50-mil centers. This feature makes TapePak compatible with existing SMD testers and handlers.

A trim-and-form tool, which attaches to standard pick-and-place machines, allows existing SMT manufacturing equipment to place TapePaks on a board along with other SMDs. Because of TapePak's finer-pitch leads however, the pick-and-place machine must be equipped with a vision-guided placement head. Just before placement, the trim-and-form tool shears off the guard ring and test points and forms the leads into a gull-wing shape. Then the pick-and-place machine's placement head picks up the prepared device and positions it on the pc board. Standard IR or vapor-phase reflow techniques can then solder all the components, whether they're SMD or TapePak devices, simultaneously.

Even though National Semiconductor has tried to make TapePak compatible with existing SMT manufacturing processes, you must still adapt your particular processes to the new package (which you must often do when introducing new SMDs to a manufacturing line). Tom Puza, assistant superintendent of manufacturing engineering at Delco Electronics Corp (Kokomo, IN), says Delco modified all the stages of its SMT manufacturing process (solder printing, device placement, reflow soldering, and repair) to accommodate TapePak. Because of its favorable experiences with the new package, Delco has added TapePak to its package arsenal along with DIPs, 50-mil SMDs, and flip chips (dies that are directly attached to a substrate). Currently, Delco employs TapePak devices in one of its car radios and will use the packaging scheme for other automotive electronic programs in the future.

National Semiconductor is not the only semiconductor vendor that is considering TAB for commercial IC packaging. Motorola Inc (Phoenix, AZ) has licensed the TapePak technology from National Semiconductor and

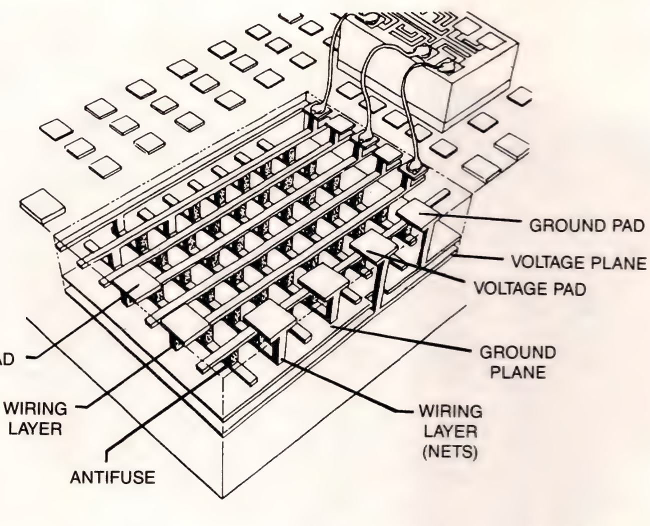


Fig 2—You can create a field-programmable hybrid circuit *by using the silicon circuit board (SCB) from Mosaic Systems Inc: You bond naked IC dies to the SCB and make electrical connections to the SCB's signal, voltage, and ground pads with wire bonds. A 20V programming pulse blows an antifuse linking one trace on the SCB's upper wiring layer to a trace on the lower layer, so you can connect the ICs mounted on the SCB.*

plans to develop its own family of TapePak ICs. Bud Simmons, manager of assembly concepts and methods engineering at Motorola, says that TAB technology such as TapePak can accommodate 500-lead ICs today; he predicts that the technology could be stretched to 1000-lead ICs in the future.

Multichip modules reduce interconnections

You can also use TAB to build multichip subsystems, because a multilayer TAB lead frame closely resembles a multilayer pc board and has similar capabilities for interconnecting ICs. In fact, some companies have already designed such multichip TAB assemblies for military contracts. For example, Texas Instruments (Dallas, TX) used multichip TAB technology to create a 288k-bit memory module for the VHSIC program. The module incorporates four 8k×9-bit static-memory dies. The TAB leads attached to the individual memory dies allowed the company to test each chip and its chip-to-lead interconnections before installing it in the multichip package.

Under another VHSIC contract, Honeywell (Minneapolis, MN) employed multichip TAB technology to create an 18-chip electro-optical image processor that incorporates two 8000-gate CMOS arrays, twelve 16k×4-bit static RAMs, and four glue chips. The entire processor fits into a small, 84-lead package. The company claims that its multichip TAB approach both reduced the image processor's requirement for pc-board space from 96 to 36 cm^2 and cut the board's power consumption to a third by lowering the capacitance of the system interconnections.

Honeywell's image processor contradicts Rent's Rule by showing that, at extremely high integration levels, lead counts may not increase with increasing IC complexity. The processor's 84 leads represent a substantial reduction in system-level interconnection when compared with the total number of pads on the chips that comprise the module. You can see similar reductions in the interconnection requirements of memory modules. For example, the 1M-byte SIMM (single-in-line memory module) reduces the system-level interconnection requirements of nine 20-lead 1M-bit dynamic RAMs—a total of 180 leads—to a mere 30 pins.

Other vendors are also experimenting with exotic multichip packaging schemes in an effort to reduce interconnection requirements at the board or system level. Mosaic Systems Inc (Fremont, CA) manufactures a user-programmable hybrid substrate that it calls the silicon circuit board (SCB). As with ceramic hybrid modules that have existed for decades, you mount bare silicon dies on the SCB's silicon substrate and use conventional wire bonds to wire the I/O pads from the attached dies to signal lines on the SCB. The SCB contains myriad uncommitted signal lines in a 2-layer matrix and provides a field-programmable method of linking those signal lines: To link them, you blow the amorphous-silicon antifuses that occupy most of the intersections in the signal-layer matrix **(Fig 2)**. The company claims that the SCB, depending on its configu-

PART FOUR
DECADE 90
The future of system design

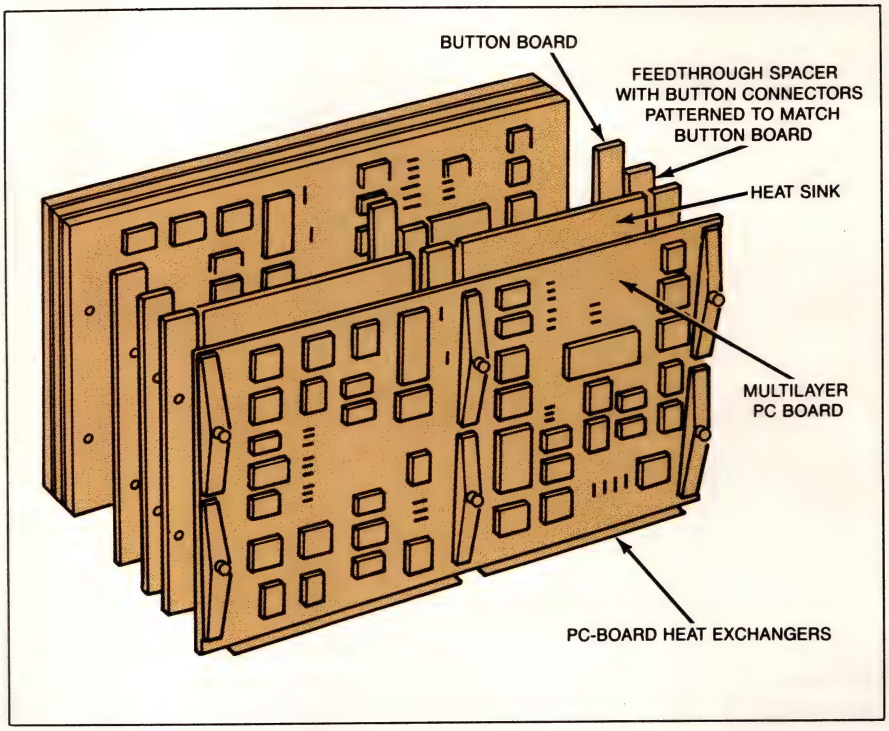


***Fig 3—Systems based on the button-board scheme** (which TRW developed for the VHSIC program) simply bolt together without a backplane. The button connectors provide interconnections between the system's pc boards, allowing you to place the circuit boards very close together, which minimizes signal-path lengths. (Figure courtesy TRW* **Quest** *magazine)*

ration, can handle signals with frequencies as high as 200 MHz.

Although a lot of packaging research is directed at device packaging, system packaging must also advance to handle the higher signal frequencies and increased complexity of future electronic systems: Traditional board-and-backplane approaches are reaching their performance limits. Because the conventional backplane topology forces the designer to place all system interconnections at one edge of a pc board, many signals must cover unduly long paths when traveling from one board to another. Long signal paths degrade system performance because they present high capacitive loads to output drivers.

Packaging a system with buttons

New system-packaging schemes are attempting to reduce these long paths. For example, TRW's (Redondo Beach, CA) patented button-connector technology allows signals to jump from board to board at any spot, not just at an edge. The button contact is deceptively simple, resembling nothing more than a miniaturized pad of steel wool. To form a connector, buttons occupy holes etched in a button board made of Photoceram, a material made by Corning Glass (Corning, NY).

You literally bolt a button-board system together, alternating Photoceram button boards with component-carrying circuit boards and topping the assembly off with reaction (pressure) plates **(Fig 3)**. The buttons touch associated pads on adjacent pc boards. Button-based systems withstand shock and vibration very well because the entire assembly is under tension from the reaction plates. TRW subjected prototype button systems to 30g vibrations for 12 hours while cycling the temperature of the system and observed no connector failures.

Bob Smolley, TRW's VHSIC assistant project manager and the creator of the button connector, says he developed the buttons in response to TRW's system requirements for the VHSIC program. He says that chips operating at bus speeds exceeding 25 MHz simply can't drive the capacitance of conventional backplanes. The 3-dimensional topology of the button board greatly reduces signal-path lengths and capacitances in comparison with those of 2-dimensional backplane systems. Not only does such an approach allow for increased signal speed, but it also reduces system power requirements, because the electrical power required to drive a signal line is directly proportional to the line capacitance. Smolley says that the button connector's ability to extract a signal from any part of a pc board, not just the edge, can also reduce signal routing, which lets you

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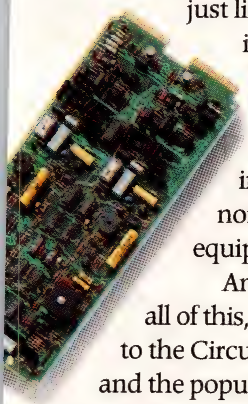

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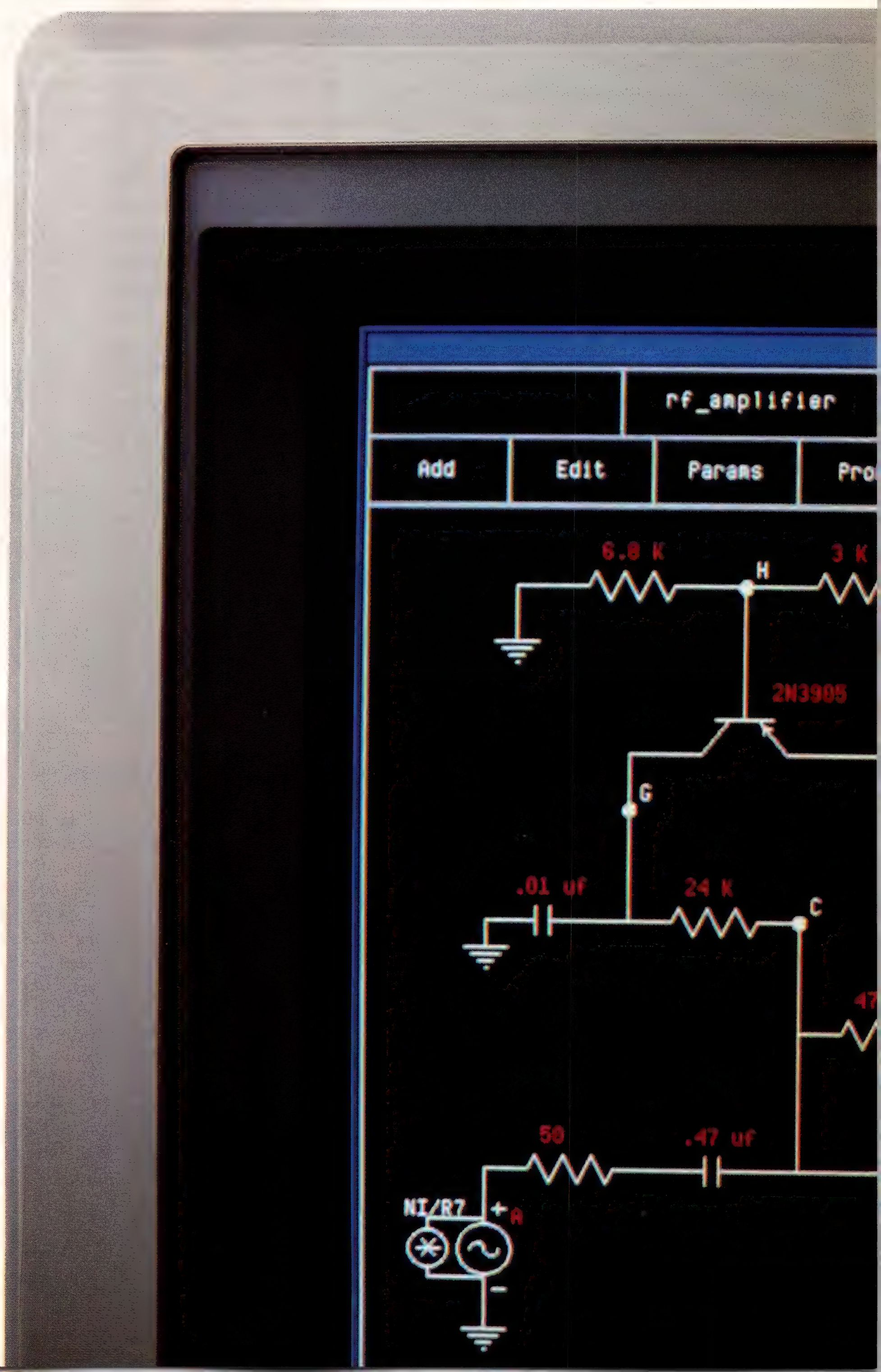

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A 3-dimensional interconnection scheme, developed by Rome Air Development Center (at Griffiss AFB in NY) and Hughes Research Laboratories (Malibu, CA) as part of their investigation of wafer-scale packaging, possibly represents the ultimate in minimal system-interconnect packaging: It uses unpackaged wafer-scale devices and connectorless interconnect technology.

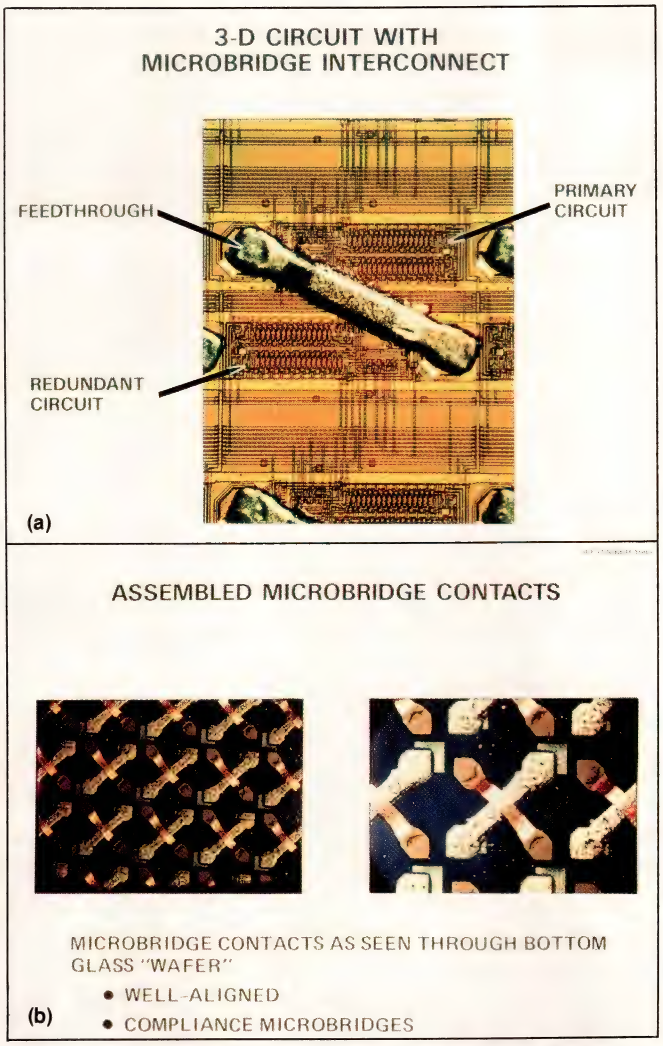

***Fig 4—Indium-coated microbridge contacts formed on both sides of a wafer-scale device (a)** allowed Rome Air Development Center and Hughes Research Laboratories to build a system by stacking several wafers. The contacts on top and bottom are orthogonal, so contacts on one wafer touch contacts on the adjacent wafer at only one point **(b)**. Applying compression to the stack slightly deflects the microbridge contacts, creating a high normal force and ensuring good physical contact during reflow soldering. After it's cooled, the soldered stack forms a complete, 3-dimensional computer system, dubbed "the coffee-can computer."*

Using this approach, engineers plate microbridge contacts on both the top and the bottom of each wafer-scale device (**Fig 4**). Feedthroughs, formed in the wafers by dissolving aluminum through the silicon with a high-temperature process, link the microbridge contacts on the top and bottom of a wafer.

After coating these microbridges with indium solder, the researchers created a finished system by stacking several wafer-scale devices so that the microbridges of one wafer contacted microbridges of abutting wafers. Heating the wafer stack while compressing it caused the indium solder to reflow, making the connections permanent and creating a completed assembly. Investigators dubbed this structure "the coffee-can computer" because of its size and configuration.

Microbridge connections create an array of interconnections that run vertically through the wafer stack. Thus, the array topologically resembles TRW's button connector, except that the array is implemented on a smaller scale. Both of these techniques represent minimalist solutions to system-level interconnection. Like these technologies, future packaging and interconnection schemes for both devices and systems will strive to place as little interconnection as possible between the output driver of one IC and the input buffer of the next chip down the line. Such approaches will provide design engineers with the dense, high-speed signal-transmission technology they'll need to build complex systems in the 1990s. **EDN**

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Article Interest Quotient (Circle One)
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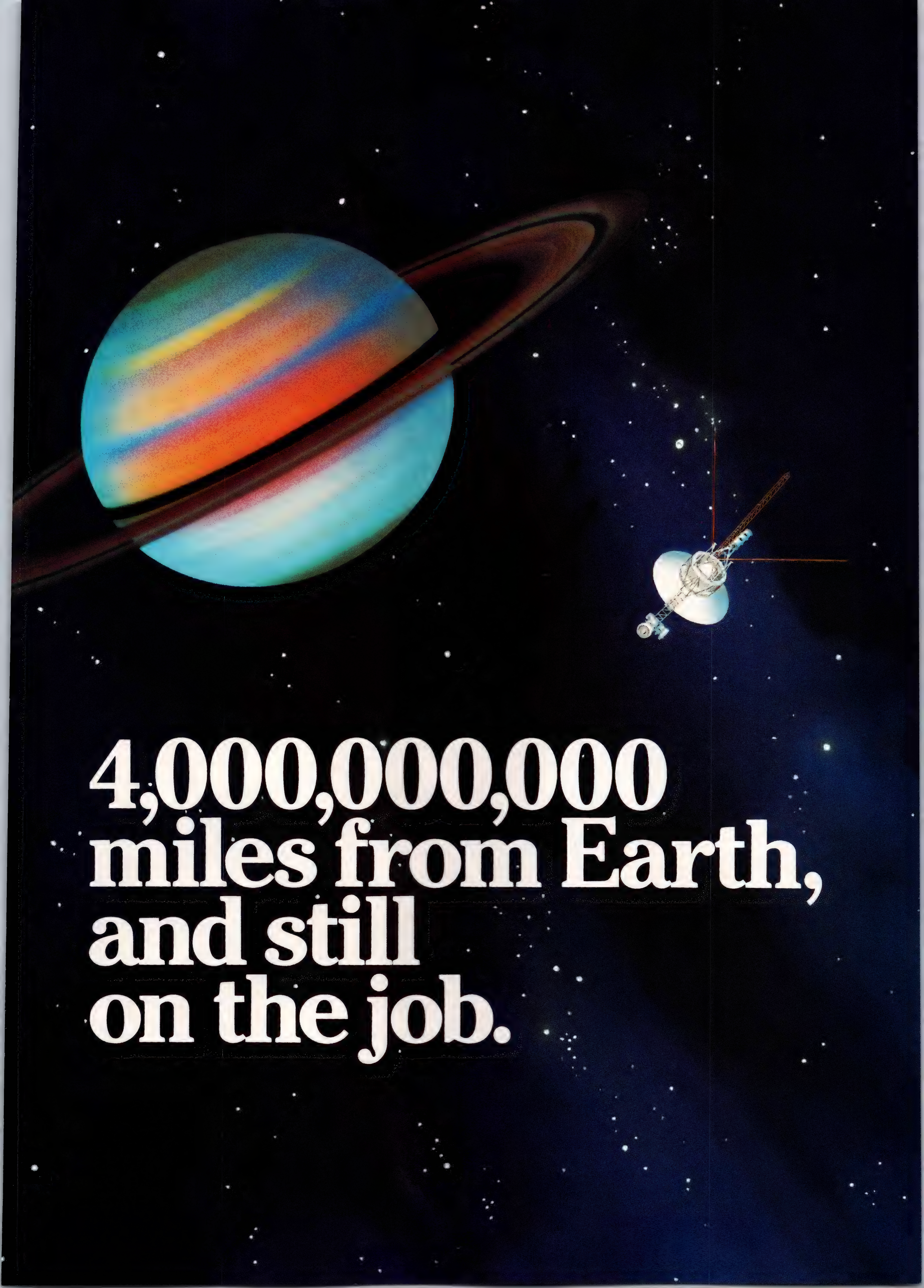
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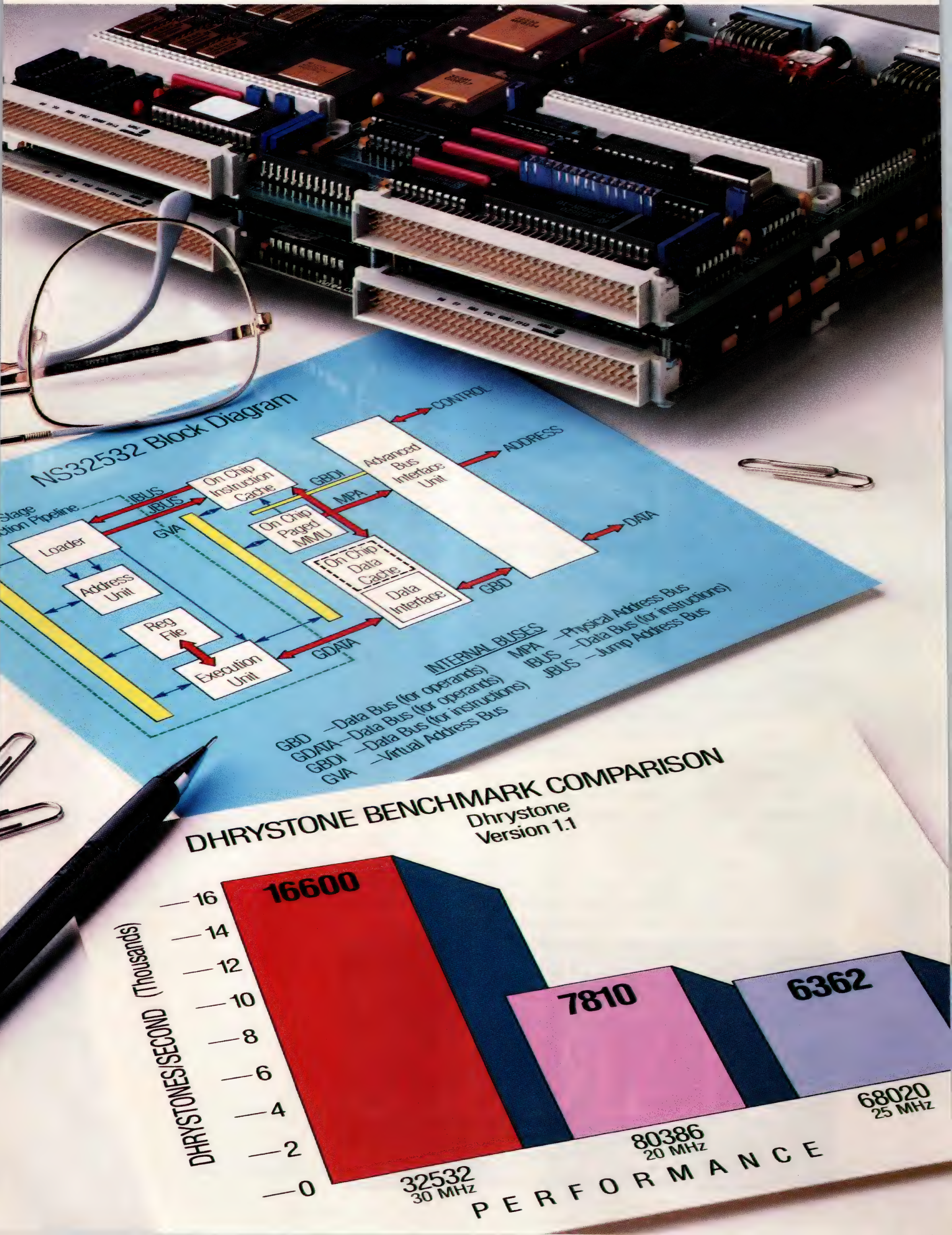

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Below: NS32532 chip
*Left: VME532 evaluation board; NS32532 block diagram; competitive performance comparison**

* *Sources:*
NS32532 — August 1987 Performance Evaluation Tests
80386 — "The 80386: A High-Performance Workstation Microprocessor," Intel Corp., June 1, 1986
68020 — SUN 3/20 @ 25 MHz, as published by Sun Microsystems

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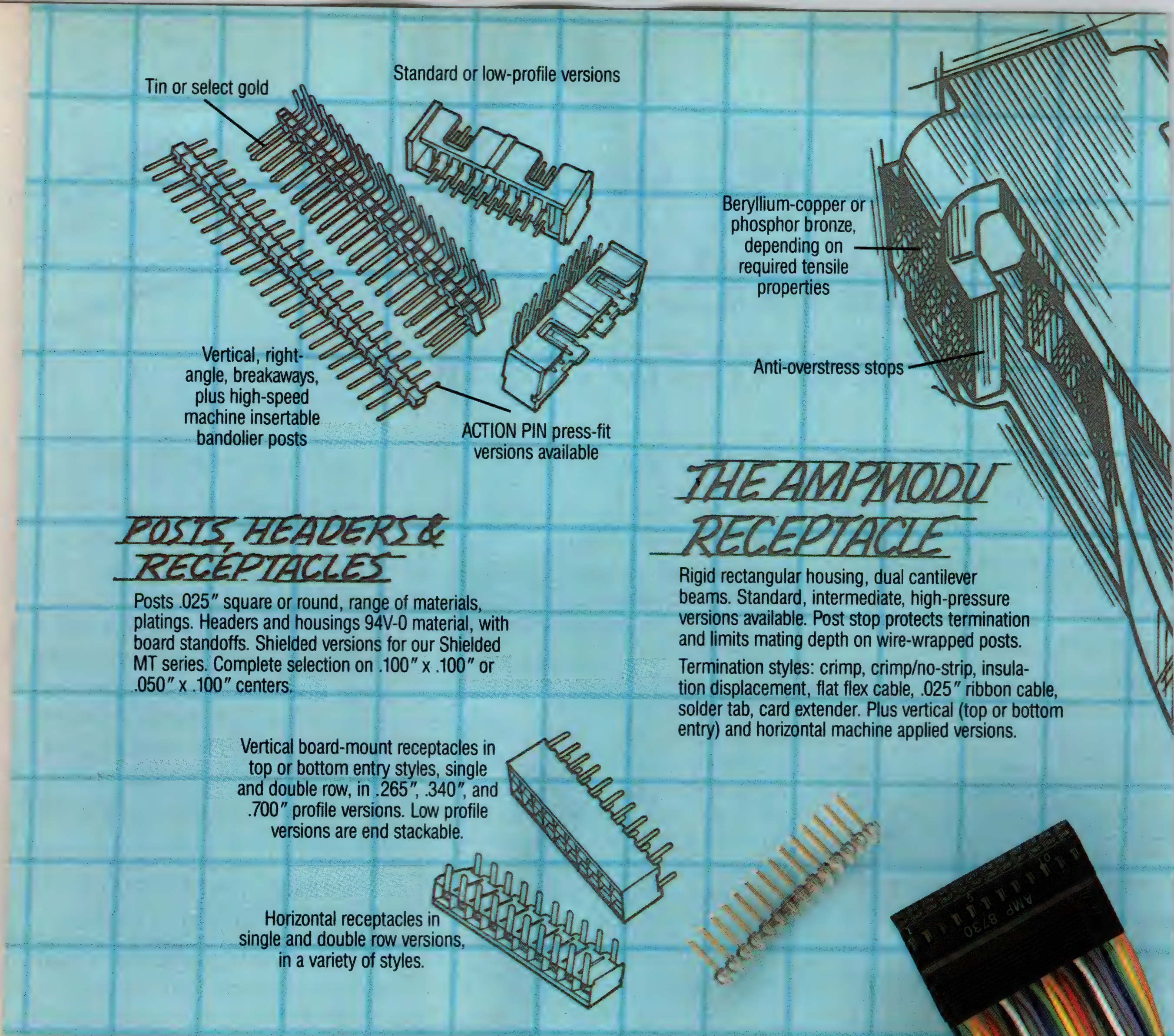

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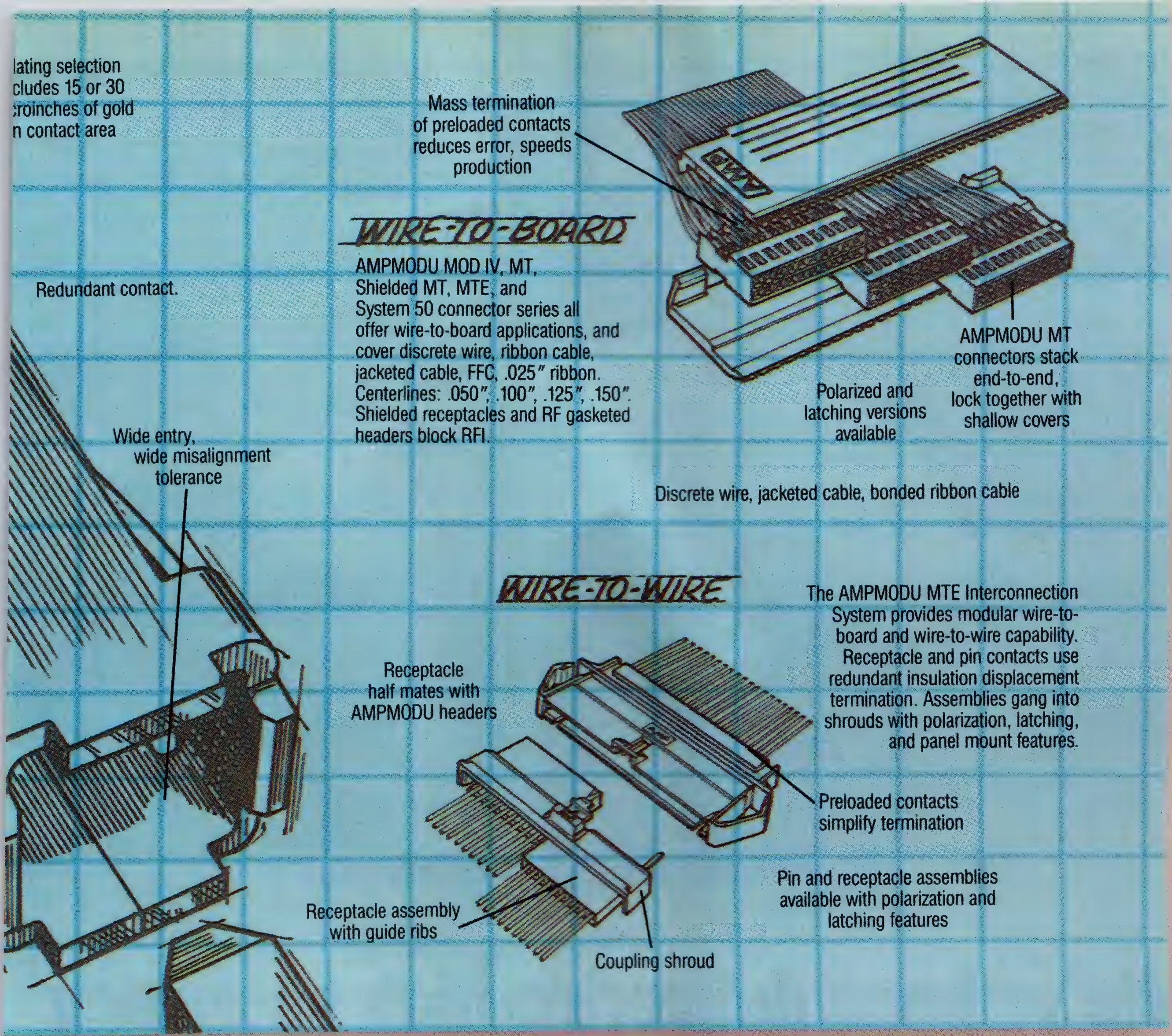

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CIRCLE NO 164

High-resolution LCD panels change demands on driver electronics

Today's LCD technology places new requirements on driver electronics—higher speed, more outputs, higher driving voltage, and lower power consumption. IC manufacturers are meeting these demands with devices that bring flat-panel LCDs one step closer to CRT performance.

Carl Fenger and Kurt Muhlemann,
Philips/Faselec

The resolution, response-time, size, and viewing-angle limitations inherent in LCD technology have made it difficult for flat-panel-display manufacturers to seriously challenge the CRT applications base. Now, however, super-twisted nematic (STN) LCD technology is overcoming these performance limitations. The new technology is changing the demands on driver electronics, but driver-IC manufacturers are keeping pace with the progress in LCDs, and the IC vendors' offerings can help you economically integrate LCD panels into your designs.

A way to increase refresh rates

Until recently, most LCDs employed a 90°-twist (twisted-nematic, or TN) technology (see **box,** "A review of LCD technology"). In flat-panel applications, you address a dot matrix of LCD pixels in a row-and-column fashion. An activation voltage scans the rows sequentially while pixel information is applied to the column drivers. At any given time, a pixel should be in either an optical on or off state.

Optimally, the LCD molecules should be in a fully twisted state when not subjected to an electric field and fully aligned when the field is present. These fully twisted and aligned states are easy to achieve for small displays, for which you can use direct-drive techniques.

Drive schemes for large displays, however, typically apply a time-multiplexed voltage waveform to activate (or deactivate) a pixel once every picture frame. Because a typical TN LCD has a relatively gradual voltage-transition region between its on and off states, the time-multiplexed drive voltage has an rms value that's not as low as the level required for full twist of the molecules but that's not as high as the level needed for full molecule alignment. The resulting intermediate states that the LCD assumes cause pixels to appear dark as the viewing angle increases. Therefore, conventional TN displays typically allow no more than 1:100 multiplexing and limit contrast ratio to 3:1 over a 15° viewing angle.

STN technology yields twist angles greater than 90° and provides a better solution for high-information-density LCDs. Most major LCD manufacturers are now developing this STN technology. With the increased twist angle, the overall liquid-crystal structure assumes a more unstable configuration—the minimum on-voltage and maximum off-voltage levels are extremely close. With a more sharply defined on/off boundary, it's possible to increase multiplex rates without degrading contrast ratio and viewing angle.

Fig 1 illustrates voltage/contrast curves for TN- and

A typical TN LCD has a relatively gradual voltage-transition region between its on and off states, which causes pixels to appear dark as the viewing angle increases.

STN-type LCDs. Curve steepness increases with increasing twist angles until it reaches a critical point at about 270°, where it has a maximum slope. At this critical point, a small change in the value of rms driving voltage produces the largest change in the tilt angle of the LCD molecules and thereby significantly changes display brightness.

Manufacturers can optimize this super-twist LCD even further by introducing active materials that ensure that the crystal has a homogeneous response. They can also introduce a pre-tilt angle to enhance the display response. This latter feature causes the super-twisted LCD to operate in a super-twisted birefringence-effect (SBE) mode that provides optimum performance when the front and rear polarizers are offset approximately 30 and 60°, respectively, from the on-axis position.

STN-type devices with twist angles of 180 to 270° (SBE) are available today for applications that require high contrast and wide viewing angles. High-performance super-twist LCDs can produce a good 7:1 contrast ratio over a 45° viewing cone. And if you operate the displays in the transmissive mode, you can use STN-type panels for high-quality computer projection. In such applications, you can operate a reflectorless LCD as an overhead projector by using a strong back light, focusing lens, and screen.

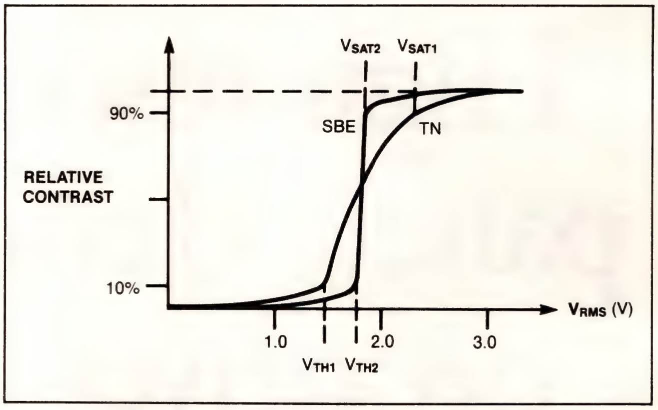


***Fig 1—Because STN-type LCDs** have a sharply defined on/off voltage boundary, a small change in the value of rms driving voltage produces a large change in the display's relative contrast.*

Drive electronics need to change

On the flip side, STN LCD technology places new requirements on the drive electronics. Higher-resolution displays and increased multiplex rates mandate the need for higher drive voltages and geometrically higher data-transfer rates. In addition, there's a relationship between multiplexing-signal drive voltage and the multiplexing rate. Fortunately, some of today's driver ICs, like the PCF 2201, let you take full advantage of STN technology. A row or column driver specifically designed for flat-panel STN LCD applications, the PCF 2201, can typically operate in systems with multiplexing rates ranging from 1:32 to 1:256.

A typical flat-panel LCD system contains an LCD dot matrix of 640 columns by 400 rows divided into two half screens of 640×200 pixels (**Fig 2**). The top and bottom column drivers control display data on the corresponding half screens. The row drivers provide the periodic strobe signals. These signals scan through each half-screen in conjunction with the multiplexed data gener-

Solving interconnect-density problems

As **Fig 2** on pg 160 illustrates, flat-panel LCD modules require a very large number of interconnections from IC to glass. Every row and column driver requires 80 connections to the display. To ensure cost-effectiveness, the interconnection process must be automated. Tape automated bonding (TAB)—a packaging scheme developed for surface-mounting applications—helps satisfy this requirement.

In the TAB scheme, small bumps of gold are galvanically grown on the bonding pads of the IC die. These bumps are then bonded to the inner leads on a 3-layer, 35-mm tape that consists of a polyimide base, adhesive, and conducting layers. These inner leads continue in a single plane to outer-lead connections.

TAB reliably satisfies low-profile, high-interconnect-density applications. The process provides high bond strength, sealed bonding pads, and flexible interconnections that maximize resistance to vibration, contamination, and thermal mismatch. In addition, TAB minimizes pad-to-pad space requirements—an aspect that is particularly attractive for high pin-count devices such as flat-panel drivers.

A review of LCD technology

LCD technology uses a class of organic materials whose optical properties change in the presence of an electric field. These materials are called nematic liquid crystals because their rod-shaped molecules, while grouped in an ordered structure, have a liquid-like freedom of movement.

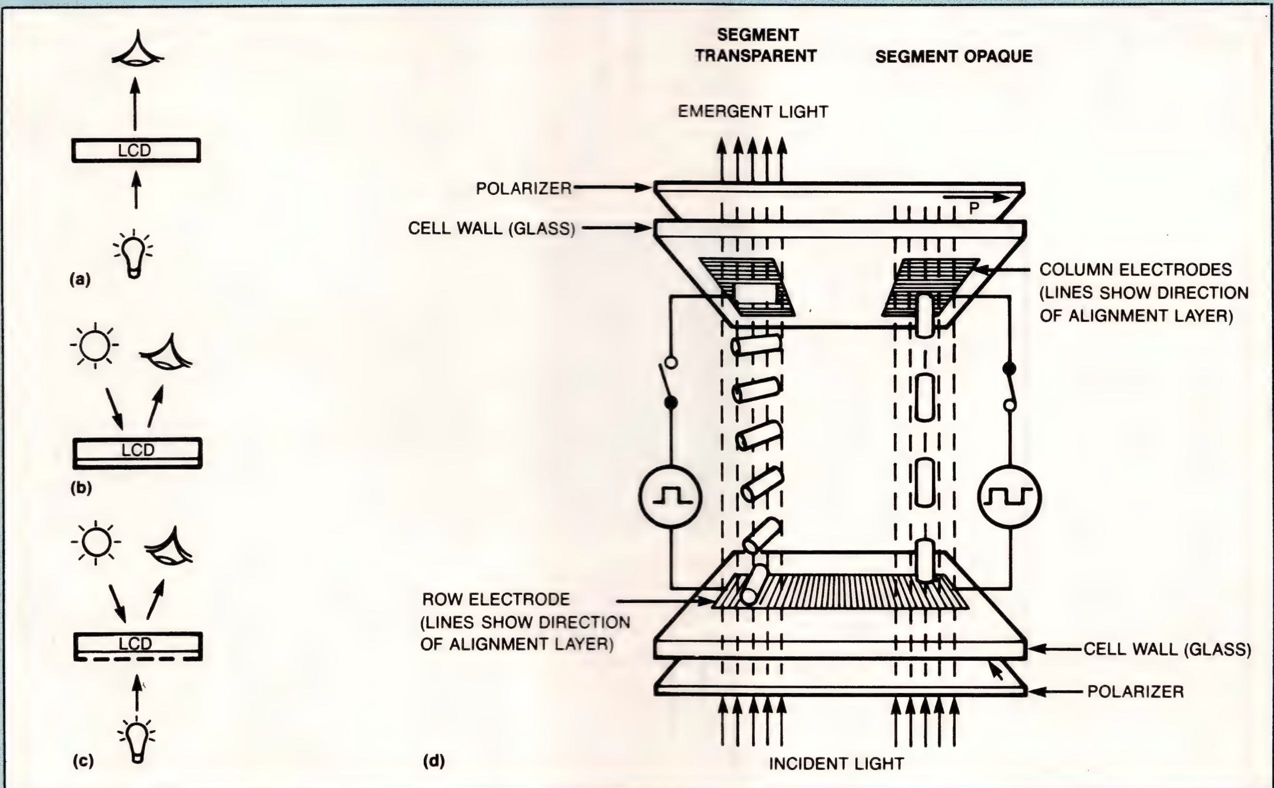
A typical LCD consists of a layer of liquid-crystal material sandwiched between two glass plates. The inside surfaces of the glass are treated so as to induce the rod-shaped molecules in the liquid-crystal material to line up horizontally in a crystalline structure. The overall shape of the liquid crystal is a helix structure twisting between one glass plate and the other. The molecules meeting the glass surface determine the angle of twist —a parameter that has a critical effect on display performance.

This liquid-crystal helix can rotate the polarization plane of light passing through it by an amount equal to the degree of twist. For a 90° twist, light entering the structure leaves with its polarization plane rotated 90°. You can break this structure down by introducing an electric field perpendicular to the glass. Such a field overrides the tendency of the molecules to form a helix; the molecules rotate to a vertically aligned position and lose their optical-modification properties. Light now passes through with the polarization unchanged. When you remove the field, the molecules return to their helical structure.

LCDs can operate in several modes. With two light-polarizing filters (90° out of phase) glued on the face and rear glass plates of the assembly, the LCD operates in either a light-absorbing or light-reflecting mode, depending on the absence or presence of an applied electric field.

In one scheme, light enters the face polarizer, and one component is filtered immediately. With no electric field present, the remaining component of polarized light rotates by 90°. The modified light component passes through the rear polarizer, reflects, and passes back out of the display in the reverse process—the display appears light.

Apply an electric field and the display operates in a light-absorbing mode. As before, the face polarizer immediately removes a component from incident light. This time, however, the liquid-crystal molecules are no longer in their helical structure, and light passes through with no polarization modification. Without this added twist, the rear polarizer absorbs the remaining, impinging light component, and the display appears dark.



LCDs can operate in a transmissive mode (a), *which requires a back light, in a reflective mode* ***(b)****, which relies on ambient light, or in a transflective mode* ***(c)****, which combines features of the other two modes. A typical LCD* ***(d)*** *consists of a layer of liquid-crystal material sandwiched between two glass plates. Shown is the 90°-twist, or TN, version; typical STN LCDs employ a 270° twist.*

STN-type devices with twist angles of 180 to 270° are available today for applications that require high contrast and wide viewing angles.

ated by the column drivers. In essence, this 640×400-pixel display is two 640×200-pixel displays that are each driven in a 1:200 multiplexed mode. The control electronics sequentially writes to each row and activates it with a pulse from the appropriate row driver.

This activating pulse (minus the corresponding column voltage) is applied to each pixel once every screen frame. The rms value of the resulting waveform turns a pixel either on or off. The PCF 2201 has a total of 80 driver outputs for either row or column operation (plus one output for margin control). Thus, the display in **Fig 2** requires a total of 21 drivers—16 for the columns and five for row control. A display controller coordinates the column and row drivers. It loads the column drivers (both upper and lower) with display information at the refresh rate and provides a row pulse once every screen frame, which propagates through all row drivers. The controller also interfaces with the display RAM, which receives its bit-mapped display data from the host system.

The display bus consists of a 4-bit data bus, which carries the display data from the graphics controller to the column drivers in 4-bit segments. Typically, you have to refresh an LCD at a rate in excess of 30 Hz to avoid flicker problems. For a 640×200-pixel panel with a refresh rate of 50 Hz, you'll need a data rate of 6.4M bps. This rate is well within the 16M-bps data-loading rate of the PCF 2201.

In **Fig 2,** the PCF 2201 connects one of six fundamental multiplexing voltages to the 80 driver outputs one row at a time in accordance with the required pixel states. These voltages are actually two sets of dual-component voltages plus a common maximum and minimum (ground) voltage. Alternating voltage sets are applied every other frame. Each set is an inverse version of the other (reflected about the voltage scale's

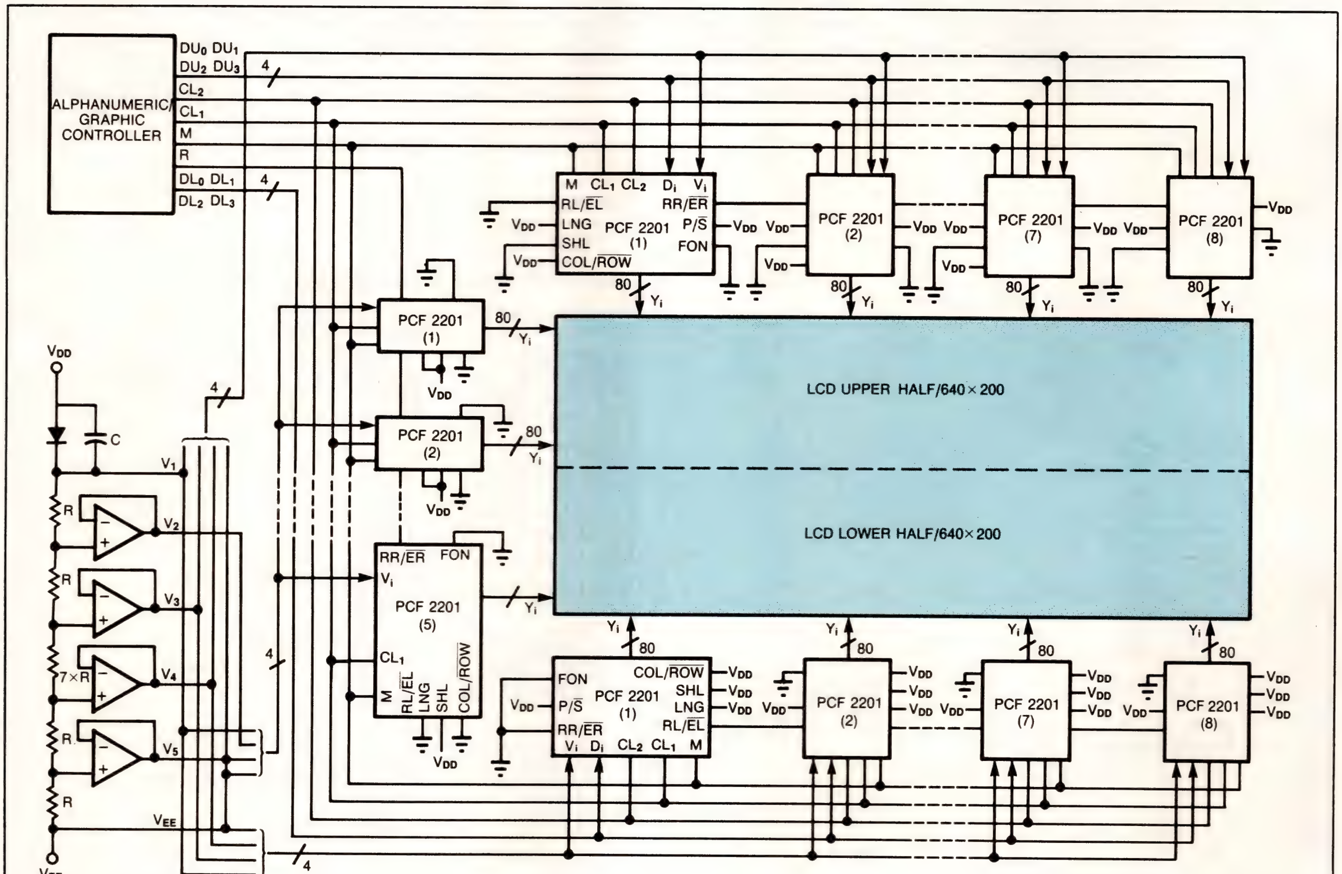


Fig 2—A typical flat-panel LCD system *contains a dot matrix of 640 columns by 400 rows divided into two half screens of 640×200 pixels. The top and bottom column drivers control display data on the corresponding half screens while the row drivers provide the periodic strobe signals.*

Take care to ensure that the LCD material does not receive a prolonged rms dc component, which could eventually break down the material's chemical structure.

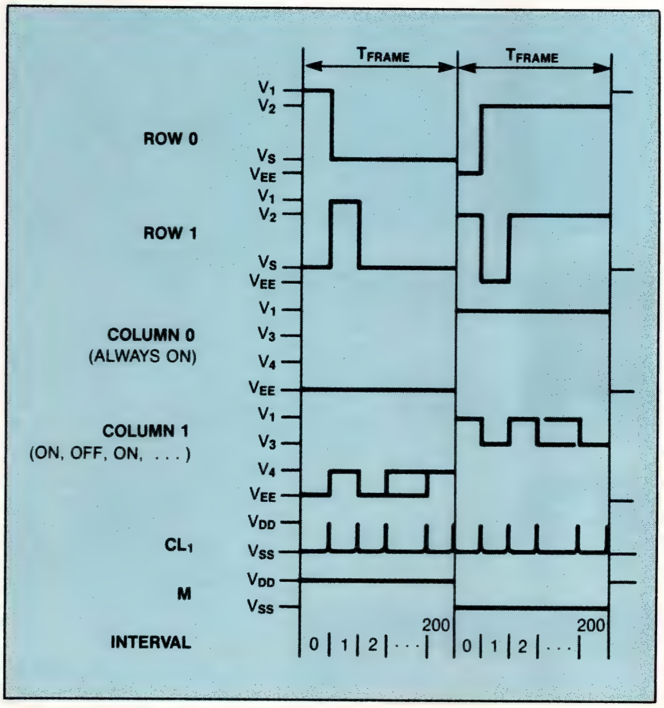


***Fig 3—To control two alternate display frames,** the drive electronics provides identical voltage-difference signals to the pixels but reverses polarities for the second frame.*

midpoint) so the LCD pixels receive the appropriate signal levels with constantly inverting polarity. This ensures that the LCD material does not receive a prolonged rms dc component, which could eventually break down the material's chemical structure.

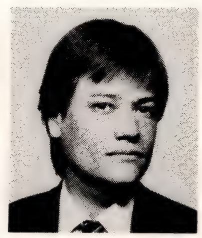
The external combination of resistors and voltage followers generates these six voltages, which the PCF 2201 then uses to generate the LCD waveforms. **Fig 3** shows typical waveforms that the PCF 2201 develops and applies to the appropriate row/column outputs to generate, first, one column with all pixels on, and second, a column with an alternating pattern of on and off pixels. **Fig 3** shows the waveforms generated for two alternate frames; the second frame shows the inverse waveforms. The pixels receive identical voltage-difference signals in both cases but with reversed polarity.

Row drivers are in control

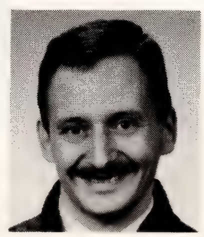
As **Fig 3** shows, the row drivers generate either an on or off voltage level. In each half display, the rows sequentially activate one at a time. All on segments receive their activating voltage component during the row pulse from their corresponding column driver. The pulse V_1-V_{EE}, occurring once each frame, darkens a specific pixel. CL_1, the clock governing the refresh rate, scans a new row and reloads all column drivers with each clock pulse. M is an input signal from the display controller that controls the generation of normal or inverted multiplexed signals.

An explicit mathematical relationship exists between the maximum number of rows and the voltage level required for the highest magnitude multiplexed signal (V_1 in **Fig 2**). The larger the display, the higher number of rows and thus the the higher the necessary multiplex rate. As multiplex rates increase, the time available to activate or refresh each row decreases, which means you need a higher driving voltage to deliver the required rms voltage. In addition, to calculate the maximum possible multiplexing rate as a function of maximum driver voltage, you need to know the LCD threshold voltage—the voltage required to obtain a 10% contrast on the LCD. **EDN**

Authors' biographies



Carl Fenger is an international product manager at Philips/Faselec (Zurich, Switzerland), where he is responsible for the worldwide marketing of CMOS peripherals. Previously, he worked as an applications engineer at the Linear Division of Signetics (Sunnyvale, CA). Carl holds a BSEE degree from the University of California. A classical pianist, Carl also likes to ski, scuba dive, and travel in his spare time.



Kurt Muhlemann is design manager for display ICs at Philips/Faselec. In this position, he is responsible for the specification, design, simulation, layout, evaluation, and release of company products. Before joining the company, he was technical manager at the Swiss IC test center in Neuchatel. Kurt received his EE degree and his PhD for multiple processor operating systems from the Swiss Federal Institute of Technology in Zurich. In his spare time, Kurt enjoys cross-country and downhill skiing, photography, literature, and music.

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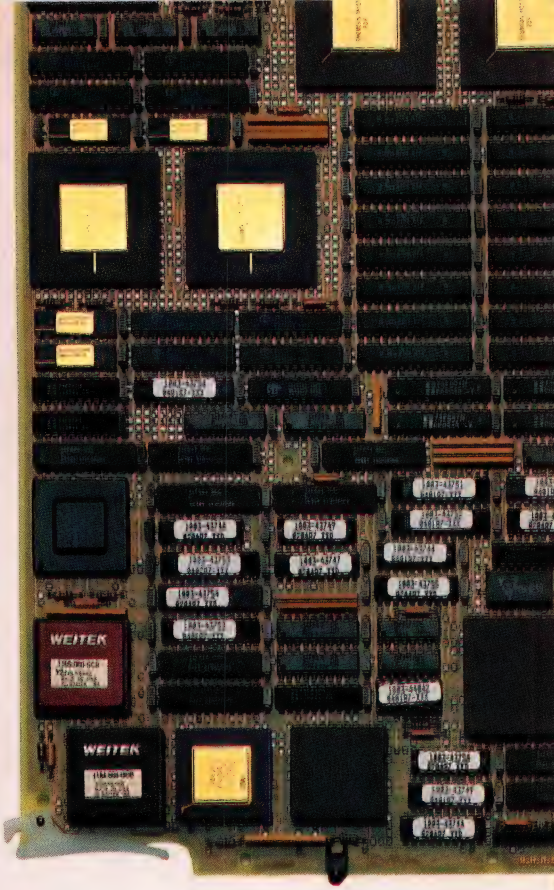

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■ Optimized for I/O with advanced constructs to simplify otherwise complex tasks. Interrupts, high speed data transfers, automatic data formatting and branching on events can all be handled easily. Since HP BASIC was designed for instrument control, these capabilities are integral, not tacked on as an afterthought.

■ Structured programming lets you make your program modular with independent subprograms which can be re-used in other applications. Constructs like CASE statements, IF-THEN-ELSE, WHILE, REPEAT-UNTIL and LOOP are useful for rapid program development and invaluable for program maintenance.

■ Powerful computation lets you take advantage of a full range of matrix manipulations such as multiplication, inversion and scalar operations. HP's complex number implementation allows for powerful arithmetic operations.

■ Graphic capabilities are simple to program, yet powerful. One program statement can draw axes or grids, a second will plot your data, a third will label your plot and a fourth will provide a permanent copy.

HP Controllers: The right horsepower for the job.

Hewlett-Packard provides a wide range of instrument controllers and operating systems to meet your performance needs, allowing you to choose the most cost effective controller for your job.

Just look:

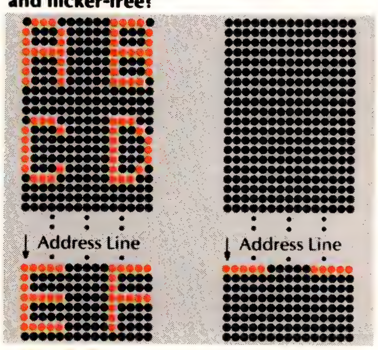
■ Personal computers; the HP BASIC Language Processor allows you to use HP BASIC on the world's most prevalent operating system, MS DOS. It's available for the HP VECTRA or the IBM PC-AT.

*Sometimes called Rocky Mountain BASIC or BASIC 5.0.

Slim and Trim

Fujitsu's extra-thin CRT-compatible plasma displays

Why Fujitsu's plasma displays are bright and flicker-free?



New Fujitsu memory-type display
All addressed lines light up simultaneously.

Conventional refresh-type display
Only one line lights up at a time.

Just 1 inch thick, the new flat-screen plasma displays from Fujitsu are ideal for today's down-sized PCs and OA equipment. Trim down your plasma panels and shape up the quality of your display.

Flicker-free: Memory-type screen writing eliminates flicker and rolling. This extra sharpness and steadiness reduces eye fatigue even during day-long use.

Extra-bright: See your data in its best light, thanks to a maximum brightness of 150 cd/m^2.

High resolution: 640 × 400 dot matrix (CRT-compatible) provides crisp displays of graphics and text.

Easy installation: All the drive circuitry is built in. Low consumption minimizes power supply requirements.

Specifications

Model: FPF8050HFUG **Dot pitch:** 0.33mm × 0.33mm **Effective display area:** 211mm (W) × 132mm (H) **Display color:** Neon orange **Contrast ratio:** 20 : 1 (min.) **Field of view:** 120° (min.) **Weight:** Approx. 1.5kg **Dimensions:** 300mm (W) × 200mm (H) × 27mm (D)

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Spice extensions dynamically model thermal properties

Thermal mismanagement can destroy high-power components and can ruin the accuracy of tightly specified analog circuits. By performing dynamic thermal analysis with an extension of Spice, the venerable electrical-circuit modeling tool, you can avoid temperature-related problems.

Eric Filseth, *Analog Design Tools*, and Mike Jachowski, *Precision Monolithics Inc*

You can extend Spice to create models that accurately depict thermal effects on analog designs—effects that range from destructive thermal runaway to inaccuracies in data-conversion circuits having resolution of 12 bits or more.

Historically, EEs have treated thermal design as a black art. Engineers have applied rules of thumb—not rigorous analysis—and circuit-simulation programs haven't been of much help. Most such programs have only rudimentary thermal-analysis capabilities. Spice is typical; it allows you to specify an ambient temperature, but it does not account for real-time effects of device-to-device coupling. So, unmodified, Spice forces you to construct circuits to find out how they will behave—just what a simulator is supposed to avoid. Spice does let you insert dependent voltage and current sources, however, and you can use that capability to build models of transient thermal phenomena.

Although temperature changes affect the accuracy of both MOS and bipolar circuits, catastrophic effects are more likely in bipolar circuits. In bipolar junction transistors (BJTs), increasing temperature raises h_{FE}, lowers V_{BE}, and as a consequence, raises the collector current (I_C). As a result, in some circuits, the BJTs' power dissipation increases with increasing temperature—which can cause a further increase in temperature and still higher dissipation. This situation is characteristic of positive thermal feedback. In MOSFETs, drain-to-source resistance increases with increasing

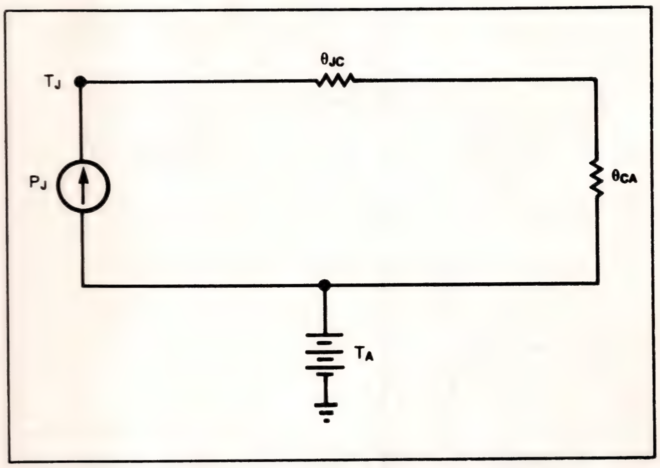


Fig 1—A static thermal model *of a bipolar junction transistor includes a power source, two thermal resistances, and the ambient temperature.*

Because of incorrectly estimated thermal feedback, chips can suffer destructive thermal runaway under supposedly benign conditions.

temperature, thus reducing drain current I_D and causing lower dissipation. This situation is characteristic of negative thermal feedback. MOSFETs tend to be thermally self-stabilizing; they are much less subject to thermal runaway than are BJTs. Therefore, this article focuses on bipolar circuits.

Ref 1 includes a good description of the most commonly used electrothermal model (ETM) for integrated circuits. The model forms an analogy between thermal systems and electric circuits: Power corresponds to current, temperature to voltage, and thermal resistance to ohmic resistance. If you choose the units correctly, Ohm's and Kirchhoff's laws apply. You can model heat sources (for instance, resistors and pn junctions) as current sources; temperature (modeled as voltage) is the dependent variable.

Fig 1 shows a simple ETM for a BJT. This model describes a discrete device or the power output stage of an IC—the part of the circuit that controls the case temperature. The thermal resistance is divided into two components: θ_{JC}, the junction-to-case thermal resistance, and θ_{CA}, the case-to-ambient-air thermal resistance. The two are frequently combined as θ_{JA}, the junction-to-ambient-air thermal resistance.

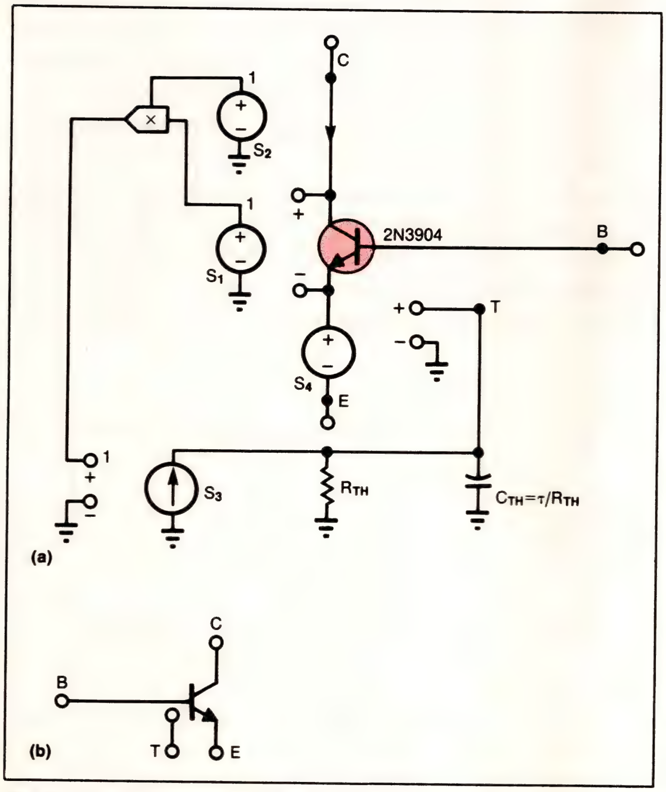


***Fig 2—A complete dynamic model (a)** includes a capacitor that simulates thermal mass. You can represent the entire model as a transistor with an extra node **(b)** and use the synthesized device in complex circuits.*

Start with a static electrothermal model

Suppose that the power dissipated in the junction of the **Fig 1** model is 100 mW and that the ambient temperature is 25°C. If the thermal resistances are 45°C/W from junction to case and 55°C/W from case to ambient, the junction temperature is

$$T_J=25°C+0.1W(45+55)°C/W=35°C.$$

The 10°C rise occurs within milliseconds after you apply power; it is great enough to measurably affect the device's performance. But the model includes no energy-storage elements (capacitors, for example), so it does not describe the dynamic effects.

The ETM is a framework that quantifies the sources and flows of heat energy in a circuit. To use a circuit-analysis tool, such as Spice, to analyze dynamic thermal phenomena, you must be able to link device behavior to junction temperature. The ETM and Spice's dependent voltage and current sources form the basis for the link. At first, however, it looks as though there is no easy way to use the link, because Spice contains no provision for calculating instantaneous junction temperatures. However, it isn't hard to link the ETM's electrical analogy into Spice.

When forming a Spice thermal model, you must make some assumptions. In reality, thermal effects and thermal resistances are nonlinear. However, linear approximations that apply over limited temperature ranges are quite accurate. For example, you can approximate the temperature-dependent change in the potential of a transistor's base-to-emitter junction as −2.2 mV/°C. An easy way to model the impact of this effect is to add a voltage-controlled voltage source in series with the transistor's base or emitter. The controlling quantity is the voltage drop produced by an imaginary current proportional to the transistor's instantaneous dissipation flowing through a pair of resistors that represent the device's θ_{JC} and θ_{CA}.

Fig 2a shows the complete model. Voltage-controlled voltage source S_1 and current-controlled voltage source S_2 generate voltages proportional to the collector-to-emitter voltage and to the collector current, respectively, of the transistor Q_1. The sources apply those voltages to a multiplier whose output voltage is proportional to the transistor's power dissipation. This

voltage controls current source S_3, whose output flows in resistor R_{TH} and capacitor C_{TH} to develop a voltage that controls voltage source S_4, which is in series with Q_1's emitter. In this model, R_{TH} is proportional to $\theta_{JC}+\theta_{CA}$. C_{TH} simulates thermal mass; because of its presence, the modeled junction temperature behaves like its real counterpart—it cannot change instantaneously. You determine the capacitor's value empirically, by measuring the thermal time constant and dividing it by the thermal resistance: that is, $C_{TH}=\tau/R_{TH}$.

What Spice doesn't know won't hurt it

As far as Spice is concerned, Q_1 is still operating at the same temperature as the rest of the circuit, but the additions shown in **Fig 2a** create a subcircuit that behaves like a transistor subject to self heating. In **Fig 2b,** this subcircuit has been compiled into a macro and given its own symbol, which includes an extra node, labeled T. That node allows you to model coupling among devices.

Fig 3a shows a common structure—a push-pull output stage using 2N3904 and 2N3906 transistors whose maximum safe continuous power dissipation without a heat sink is about 350 mW at an ambient-air temperature of 25°C. In this example, all devices are discrete, and there is no thermal coupling among them. R_{TH}, which, in this case, models θ_{JC}, is 125 °C/W, a typical value for small-geometry plastic-cased devices. τ is 1 msec. The use of θ_{JC} rather than θ_{JA} assumes that, for the short period modeled by the simulation, the devices' case temperatures remain constant. That assumption, incidentally, supports the absence of coupling among devices.

Because the goal is a dynamic thermal analysis, a 30V step applied to the power-supply terminals is used to model the effect of powering up with ±15V supplies. If you make $R_E=10\Omega$, the no-load quiescent current through the transistors is slightly greater than 10 mA. **Fig 3b** shows a family of plots generated by the Analog Workbench (see **box,** "Focus on your circuit, not your simulator").

These plots represent the buildup of current after application of power with several different values of R_E. The lowest curve represents $R_E=10\Omega$. In the top curve, $R_E=0\Omega$, and within milliseconds after power is applied, the transistors are dissipating several watts, a destructive condition. In fact, if $R_E=0\Omega$, within a few milliseconds, the temperature becomes so high that the 2.2-mV/°C model probably no longer applies. Nevertheless, the thermal runaway is clearly shown: Destruction of the transistors is not instantaneous; it occurs over a period of milliseconds as the result of positive thermal feedback—accurately modeled by the Spice extensions.

The circuit of **Fig 4a** illustrates how the Spice extensions handle thermal coupling between devices. Q_1 and Q_2 form a current mirror in the gain stage of a wideband hybrid operational amplifier. To achieve wide bandwidth and the largest possible signal swing, a

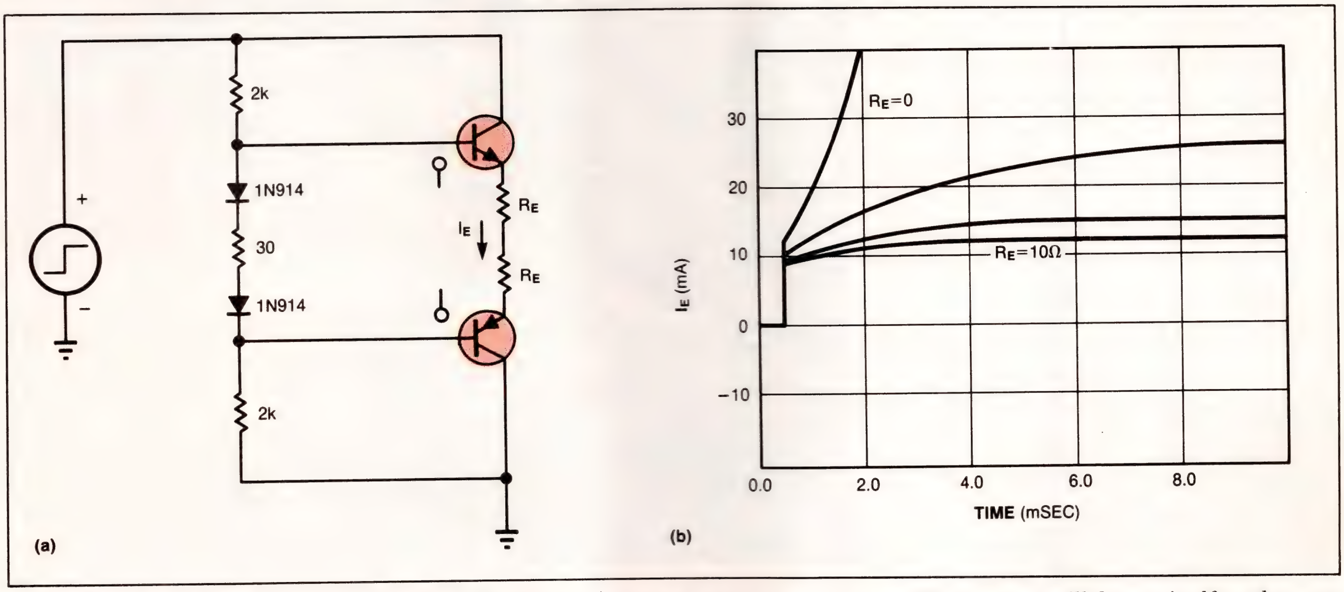


Fig 3—If you make the degeneration resistance *in the complementary output stage* ***(a)*** *too small, the circuit will destroy itself, as the upper curve of the current-vs-time graph* ***(b)*** *illustrates.*

When you design analog circuits having resolution of 12 bits or more, you must maintain a constant vigil, lest thermal effects wreck your circuits' accuracy.

2-transistor mirror is used, rather than a more complex structure. The mirror's accuracy depends on both the electrical and thermal matching of the devices. Q_1 is connected as a diode; the voltage across it is approximately 0.7V, a value that varies little. Q_2 is a common-emitter stage whose V_{CE} makes large swings. The currents through Q_1 and Q_2 are constant and—ideally—virtually equal. Because of its large and variable V_{CE}, Q_2's dissipation varies over a wide range. R_{JJ} represents the thermal resistance between Q_1 and Q_2. Without good thermal coupling between the devices, Q_2's higher dissipation will make its temperature higher than Q_1's and spoil the transistor-to-transistor match.

Suppose you connect the amplifier to produce a noninverting gain of 100 and apply a 100-mV step to the input. As with the earlier push-pull-output-stage example, assume that, for the period modeled by the simulation, the amplifier's case temperature remains con-

Focus on your circuit, not your simulator

As every engineer who has used stand-alone Spice can attest, simulation tools have traditionally dragged designers away from their circuits and into performing the mechanical operations necessary to comply with the simulator's requirements. Building net lists and numbering nodes is so tedious and so different from circuit design that many engineers will do whatever they can to avoid using a stand-alone simulator.

Computer-aided circuit-simulation tools, of which Spice is the best known, offer distinct improvements in areas such as accurate representation of IC characteristics. But a good workstation environment allows engineers to ignore the simulator and to concentrate on the circuit under development. Instead of acting as a barrier between the engineer and the circuit, Spice operating in a workstation environment becomes what its creators intended it to be: a calculating engine. No longer does the cure (simulation) seem worse than the disease (seat-of-the-pants design).

The circuits in this article, "built" and "tested" (actually simulated) with Spice running under the Analog Workbench design environment from Analog Design Tools, demonstrate modern CAE tools' capabilities.

To create the circuits, the authors used the Workbench's Circuit Editor and the dynamic thermal model of a 2N3904 transistor contained in the Workbench's general device library. The devices contained in the li-

***An interactive** windowing environment allows designers who use Analog Design Tools' Analog Workbench to experiment with circuit models on a variety of workstations.*

stant. (In the hybrid circuit, however, thermal coupling among devices is important.) Under these conditions, the pertinent thermal resistances are θ_{JC}, which equals 70°C/W, and θ_{JJ} (corresponding to R_{JJ} in **Fig 4a**), the effect of whose value you will model in successive simulation runs.

If θ_{JJ}=3°C/W, you obtain the almost perfectly square response shown in **Fig 4b.** You can't achieve response this good if you use discrete transistors for Q_1 and Q_2—even discrete chips mounted close together on a ceramic substrate, because with discrete transistors θ_{JJ} will be more than an order of magnitude higher than 3°C/W. To achieve the nearly perfect response illustrated, you need to use a monolithic transistor pair, such as PMI's MAT-01. In such devices, $\theta_{JJ}\approx$0.5°C/W, nearly an order of magnitude *better* than the coupling that produces the square response.

If θ_{JJ}=45°C/W, a more realistic value for discrete

brary, more than 1400 at this writing, are documented in a device data book; data includes maximum operating conditions, thermal characteristics, and the plots of characteristic curves. This information can easily be compared to that in real device data books.

Not wanting to complicate their circuit design with all the detail in the schematic of this transistor, the authors used the Workbench to transform the circuit into a macro and to design a custom symbol for it.

It takes time to build a test setup in the lab. You can tweak a breadboard endlessly and still not learn all you need to know. For example, when the authors set up one amplifier circuit for lab tests, they had to set the gain extremely high—close to the open-loop gain of the op amp. The high gain made it difficult to keep the offset from running the output into the rail. Manual zeroing of the offset was necessary. Because the offset error changed with the room temperature, it took a half an hour and a good bit of tweaking to get it right.

Using stand-alone Spice to set up a circuit for testing would have been equally time consuming, because entering (and altering) circuit characteristics can require a lot of programming. Whether at the lab bench or using a stand-alone simulator, designers spend an inordinate amount of time on activities only marginally related to designing a circuit and verifying its performance. Using the Analog Workbench, they can accomplish a delicate offset tweak in a few minutes, simply by typing in a new value for an offset generator inserted into the circuit.

Advanced CAE tools also make it possible to simulate measurements that would be difficult on a breadboard. You can attach "probes" to any point on an integrated circuit, not just to the inputs and outputs. So measuring the parasitic signals inside the chip, as was done with the thermally coupled npn transistors, is done by attaching the probe with the mouse, calling up the parametric plotter, and running the analysis. The Workbench displays the results immediately, and tweak adjustments take a few seconds.

Simulated test instruments, such as the oscilloscope used to determine the settling of the amplifier in this article, are also included in advanced CAE tools. Other bench instruments include multichannel function generators, frequency sweepers, multichannel network analyzers, dc multimeters, and spectrum analyzers. The CRT displays controls that function like the knobs on real test instruments.

In addition to the parametric plotter used in this example, computer-based Monte Carlo and sensitivity/worst-case tools provide in-depth analyses quickly and reliably. Stress-analysis tools can also be used to identify overstressed components. Good conceptual design is as much a visual as a cerebral exercise, and the smoke icons that identify stressed components in the Analog Workbench's smoke alarm function as a powerful visual indicator of areas that need further attention.

In a sense, the advancement of CAE tools is evidenced by the fact that they are now rooted in the methods engineers have used for years. As a result, an engineer's intuition and knowledge are leveraged by an environment that supports time-tested creative engineering methods while providing the number-crunching and analysis functions best accomplished by a computer.

Historically, EEs have treated thermal design as a black art.

chips on a ceramic substrate, you obtain the response shown in the lower curve of **Fig 4b.** Initially, the transistors are matched, but soon after the voltage step, Q_2's increased dissipation begins to raise its temperature above that of Q_1. Eventually, the devices reach thermal equilibrium, but their temperatures are no longer equal. As long as the voltage step persists, Q_1 will be hotter than Q_2. The thermal transient, as seen at the amplifier output, takes 1 msec to settle to within 25 mV of final value (approximately 0.6 LSB in an 8-bit system with a 10V full-scale range) and a full second to settle to within 1.2 mV of final value (0.5 LSB in a 12-bit, 10V-full-scale system). Clearly, the discrete current mirror, with its long thermal tail, is not well suited for use in an amplifier preceding even a moderately accurate ADC in a high-speed system.

If two supposedly identical BJTs operated under identical conditions exhibit a differential base-to-emitter junction potential (that is, $V_{BE1}-V_{BE2}$) equal to V_{OS}, the temperature coefficient of the differential voltage will be V_{OS}/T (in V/°C), where T is expressed in degrees Kelvin. So, in theory, a bipolar-input operational amplifier that exhibits a V_{OS} of 1 mV will exhibit a dV_{OS}/dT of 3.33 μV/°C at 23°C (300°K). Many modern low-drift monolithic operational amplifiers contain input circuits that reduce initial offset, so they do not perform as the preceding analysis might lead you to expect. This circuit sophistication can complicate the job of modeling an op amp's offset-voltage drift vs temperature.

Nonetheless, you can use the modeling techniques described here in conjunction with an op amp's maximum offset-voltage-drift spec to predict an error band

Automate thermal-resistance measurements

Thermal resistance, θ, is a consequence of mechanical—not electrical—properties of all semiconductor devices. Two factors exert a major influence on θ: die size and package characteristics. You can predict the thermal resistance of a new device with good accuracy by using the value previously determined for a chip of similar size mounted in a similar package. Extrapolations usually work, too. For example, if an op amp in an 8-pin ceramic DIP has a θ_{JC} of 10°C/W, a voltage reference with half the chip area in an 8-pin ceramic DIP will have a θ_{JC} of approximately 20°C/W.

Predicting θ_{JA} is even easier. For most plastic- and ceramic-cased ICs, θ_{CA} is the dominant term in θ_{JA}. θ_{CA} for such devices is mainly a function of package size. Mini-DIP packages with eight leads exhibit roughly twice the θ_{CA} of 16-pin DIPs.

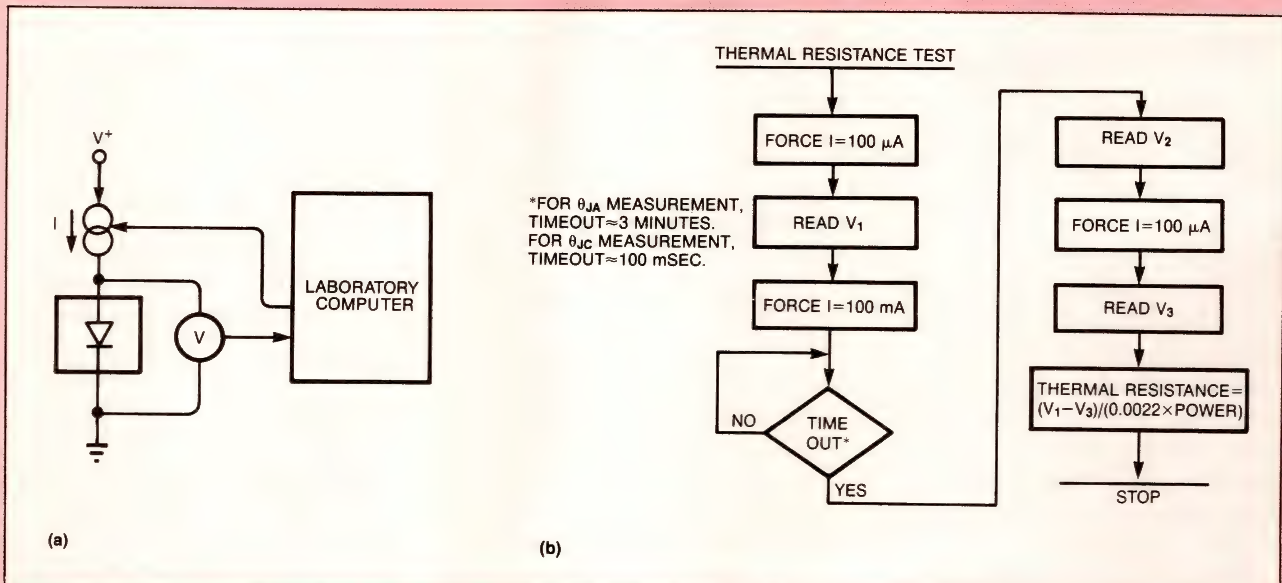


*Fig A—A laboratory data-acquisition system **(a)** simplifies measurement of a device's thermal resistance. The flow chart **(b)** shows the steps required.*

surrounding the device's output voltage. Four factors can influence a monolithic op amp's offset voltage by affecting its junction temperature: quiescent dissipation, signal-induced dissipation, ambient temperature, and heat sinking. Of these factors, the most easily understood is ambient temperature. There is a one-to-one correspondence between ambient- and junction-temperature changes.

Heat sinking is fairly easy to understand. It affects a device's junction temperature by affecting θ_{JA}. With a heat sink attached to its case, a device's junction-to-ambient-air thermal resistance consists of three elements in series instead of the two discussed ealier:

$$\theta_{JA}=\theta_{JC}+\theta_{CS}+\theta_{SA},$$

where θ_{CS} is case-to-heat-sink thermal resistance and θ_{SA} is heat-sink-to-ambient-air thermal resistance. Because $\theta_{CS}+\theta_{SA}<\theta_{CA}$, the junction-temperature rise above ambient temperature is reduced by attaching a heat sink to the device's case.

Air velocity can affect circuit performance

Remember, too, that with or without a heat sink, the velocity of the air moving past a device affects its case-to-ambient-air thermal resistance, and hence its junction temperature. An old story provides a good illustration of the effect of varying air velocity on T_J: A low-level signal amplifier breadboard was suspected of oscillating at an amplitude equivalent to about 15 μV p-p referred to its input with a frequency of about 0.5 Hz. Eventually, the designer traced the oscillation to

Although such predictions are useful, they frequently fail to provide information needed to forecast errors in analog ICs. A computer-based laboratory data-acquisition system can enable you to make thermal resistance measurements on ICs and discrete components rapidly and with relative ease. However, hybrid circuits can present a special challenge; they can contain chips whose temperature you want to measure but that are inaccessible from the package's pins.

Fig A shows a typical setup and flow chart for measuring θ. A current source forces current into the DUT (device under test). The voltmeter reading multiplied by the source current equals the power dissipated. The computer is handy not only for data analysis but also for controlling the current source. The test takes advantage of a component present in all semiconductors—the pn junction. Bipolar integrated circuits (except dielectrically isolated devices) contain pn parasitic junctions between the power-supply terminals. When measuring the temperature of an IC, these parasitic junctions are the best available thermometers. MOS devices contain them, too.

The basic idea is to measure the diode's forward voltage cold, then deliver a known amount of power to the chip and measure the forward voltage hot. If you deliver the same current to the diode whenever you measure its forward voltage, you can determine the junction-temperature rise from the −2.2-mV/°C temperature coefficient. A measurement current of 100 μA is a good choice; it won't heat the diode excessively, nor will it create significant voltage drops across resistances (of bonding wires, for example) in series with the diode. You calculate θ as temperature rise divided by power.

For θ_{JA} measurements, a heating power of 100 mW is adequate. The DUT should be exposed to still air with nothing touching the case. No breezes should be allowed to provide cooling. Heating must continue until the device reaches thermal equilibrium; it is not unreasonable to allow two to four minutes. The speed of the data-acquisition system comes in very handy at this point. It is important to check the junction temperature within about a millisecond after removing the heating power—before the DUT can cool down.

In contrast, the procedure for θ_{JC} measurements is quicker. You have to apply power only long enough for the chip to warm up; you must remove power before the chip warms the package. Because θ_{JC} is much lower than θ_{JA}, you may need to dissipate more power (200 to 400 mW) to achieve a significant temperature rise. If the package temperature remains constant, the chip temperature rise divided by the applied power represents θ_{JC}.

Spice forces you to construct circuits to find out how they will behave—just what a simulator is supposed to avoid.

Model thermal effects on Rs and Cs in ICs

Fig A shows a model for an integrated resistor whose room-temperature resistance is R_0:

$$R=R_0(1+\alpha\times10^{-6}\Delta T),$$

where α is a temperature coefficient expressed in ppm/°C and ΔT is a temperature change in °C. The temperature effects are modeled by a voltage source in series with the resistor. The source's value is derived in the equations at the bottom of **Fig A.** The model is a little more complex than the transistor's thermal model because the source voltage depends on both the voltage drop across R_0 and the ΔT.

Fig B shows a model for a junction capacitor:

$$I=C(dV/dt)$$
$$=C_0(dV/dt)+(\alpha\times10^{-6}\Delta T)dV/dt.$$

A current source, whose value depends on the rate of change of voltage across C_0, models the temperature dependence. Note that, although the capacitor is affected by the chip temperature, it dissipates no energy and is not, itself, a heat source.

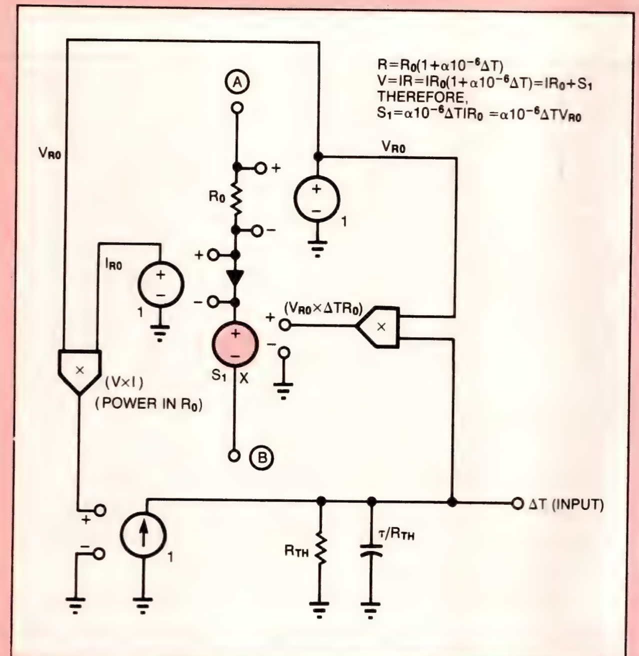


Fig A—This model of an integrated resistor uses a voltage-controlled voltage source to model the effects of temperature.

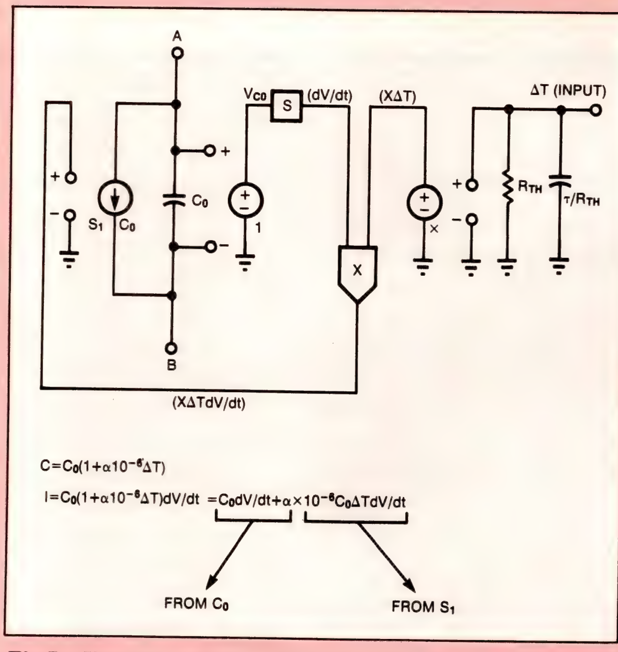


Fig B—You can model the effects of varying temperature on an integrated capacitor by shunting the capacitor with a voltage-controlled current source.

an oscillating electric fan on a lab bench many feet away. Whenever the air stream from the fan swept over the breadboard, it lowered the θ_{JA} of the input device, and hence lowered its T_J. Because of the amplifier's nonzero dV_{OS}/dT, the amplifier converted the fan's motion into a varying output voltage.

A device's quiescent dissipation goes from zero to some nonzero value when you apply power. The preceding statement might seem trivial, but it implies the significance of the methods IC manufacturers use to test and trim their parts. Low-initial-offset op amps often undergo a trimming operation as part of the manufacturing process. Usually, this operation is performed at high speed on automatic test equipment. Often, it is impractical to allow enough time for the devices to reach normal operating temperature before trimming them. A vendor who trims an op amp before its temperature stabilizes must know what the amplifier's offset *would have been* had he allowed sufficient stabilization time. If the internal trims null the offset before the device warms up fully, the additional offset (that is, the difference between the nulled offset and the

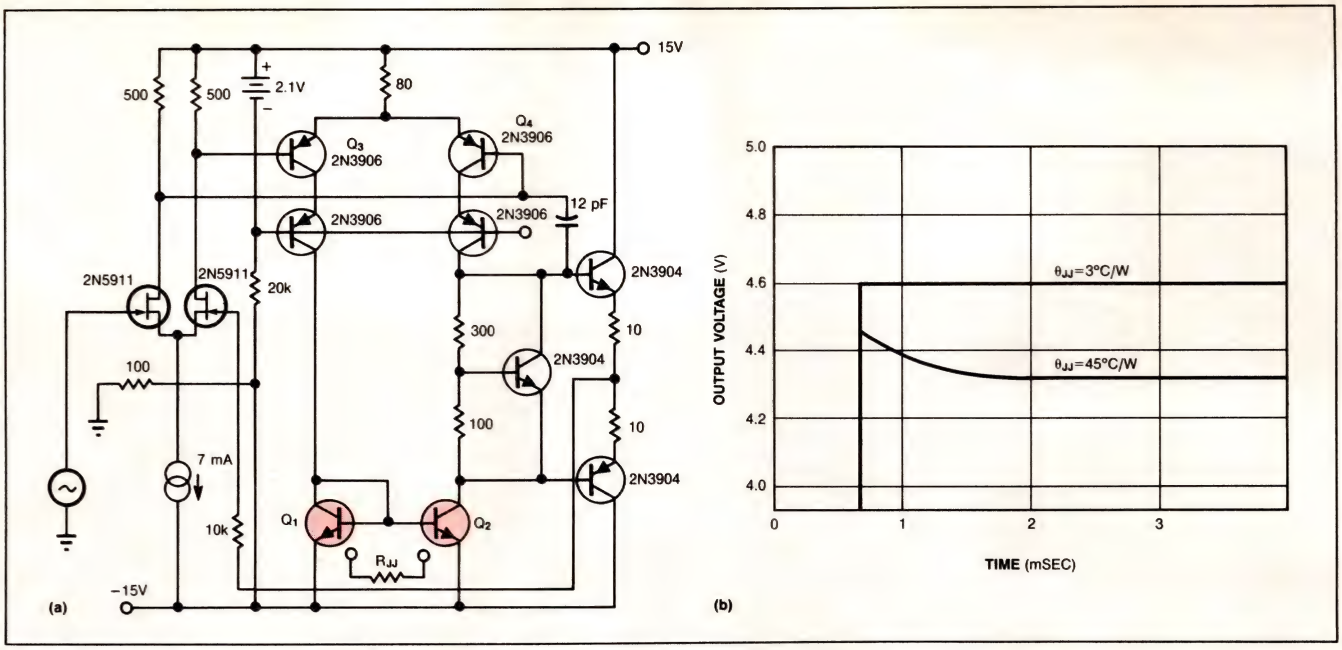


*Fig 4—**If you use discrete transistors** to build the current mirror consisting of Q_1 and Q_2 **(a)**, signal-induced dissipation causes the amplifier output to exhibit a long tail, as indicated by the lower curve of the voltage-vs-time graph **(b)**.*

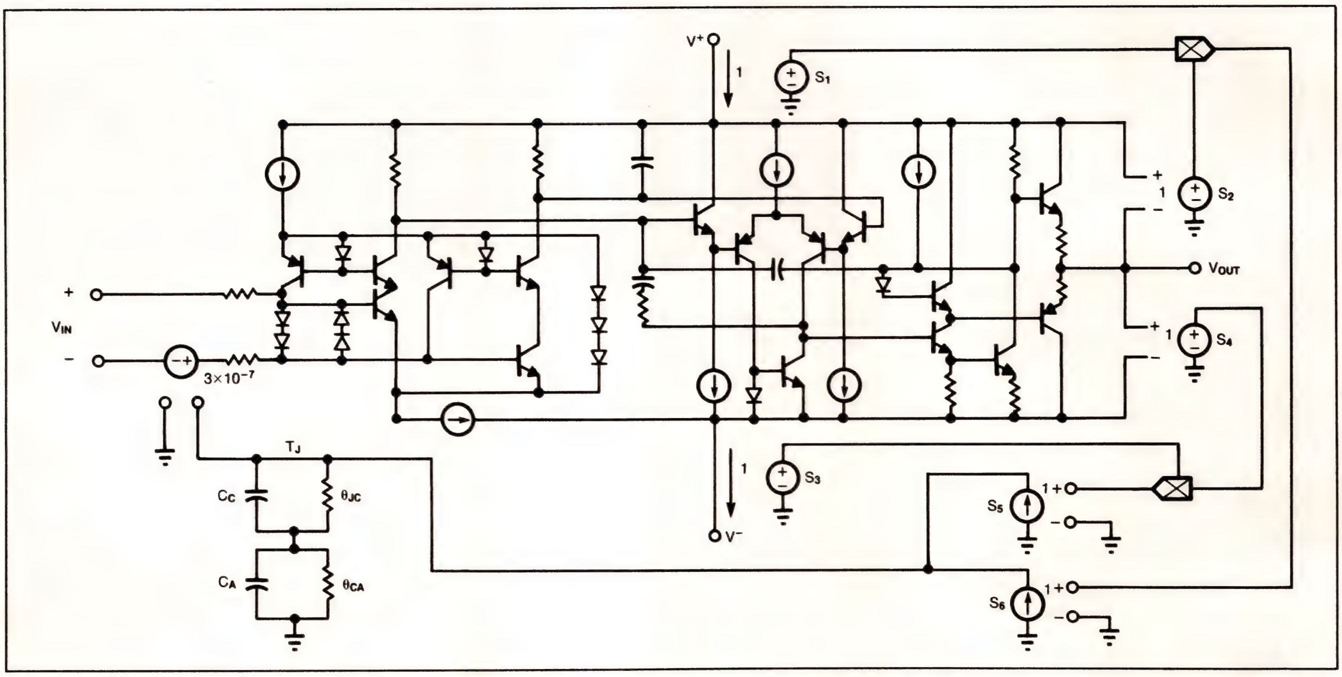


*Fig 5—**Close examination of the simplified schematic** of PMI's OP-77 indicates the similarity between the techniques used for thermal modeling of ICs and discrete devices.*

offset that would have been nulled if sufficient stabilization time had been allowed) becomes part of the error band mentioned earlier.

Signal-induced dissipation can add errors

The current-mirror circuit of **Fig 4** provides a good example of the effect of signal-induced dissipation. When the output changes by 10V, Q_2's dissipation changes by 10V×I_C, where I_C is the collector current. If I_C=2 mA, the 10V output swing causes a 20-mW change in the chip's dissipation. If the current mirror is part of an op amp, and the thermal resistances are not absolutely identical from Q_2 to both transistors of the input differential pair that governs the amplifier's V_{OS}, the signal-induced dissipation will warm one side of the differential pair more than the other. The temperature difference, which takes milliseconds to develop, will cause V_{OS} to change because of the −2.2-mV/°C temperature coefficient of V_{BE}. If you can determine the thermal resistance from Q_2 to each input transistor, the Spice extensions can model the effect, and the effect becomes part of the device's error band.

Fig 5, a simplified schematic of PMI's OP-77 precision op amp, illustrates that to model the effects of an IC's internal power dissipation, you can use the same techniques you use to model the effects of internal dissipa-

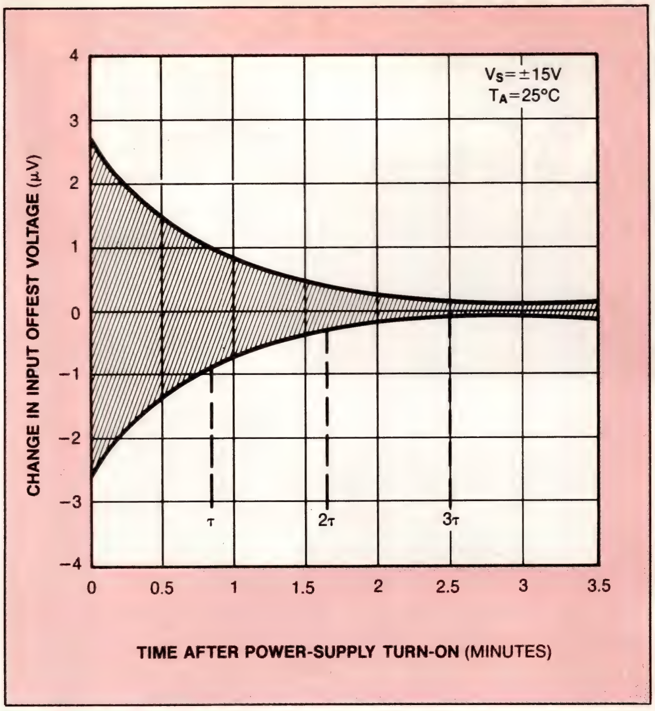


Fig 6—The offset voltage *of a precision op amp (PMI's OP-77) changes as the device warms up. The curves indicate a junction-to-ambient-air thermal time constant of about 50 sec.*

tion in a discrete transistor. The schematic shows a controlled voltage source with a scale factor equal to the device's specified voltage-offset temperature coefficient in series with the input. The outputs of two controlled current sources, S_5 and S_6, flow through the series combination of a pair of RC networks to provide the input source's control voltage. A multiplier, which computes the product $I^-(V_{OUT}-V^-)$, drives S_5; a second multiplier, which computes the product $I^+(V^+-V_{OUT})$, drives S_6. V^+ and V^- are the supply voltages; I^+ and I^- are the corresponding supply currents.

The RC networks represent the junction-to-case and the case-to-ambient-air time constants; in typical ICs their values are 0.5 to 5 sec and 30 to 120 sec, respectively. Because the internal time constant is only 1/6 to 1/240 as large as the external one, and because θ_{CA} is much greater than θ_{JC}, you can often safely use only θ_{JA} and its associated time constant, which are nearly the same as θ_{CA} and its time constant. **Fig 6** shows how the OP-77's offset voltage changes as the device warms up. The exponential decay of the offset change reveals θ_{JA}'s time constant.

For best results, play by the rules

The following precautions can help you avoid thermal errors in high-accuracy analog systems:

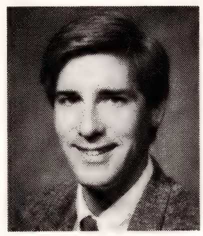
- Use amplifiers specified to have low voltage-offset temperature coefficients.
- Use the lowest practical supply voltages to minimize internal dissipation.
- Avoid using precise high-gain amplifiers to directly drive even medium-power loads. Interpose separately packaged devices as buffers between critical gain blocks and loads.
- Remember to include the load imposed by feedback networks when calculating an amplifier's dissipation.
- Locate high-dissipation components as far as possible from temperature-sensitive components.
- Select devices in packages that have low thermal resistance. Ceramic packages, although more expensive, have lower θ_{JC} than do plastic packages.
- Use heat sinks where appropriate. Although this caveat doesn't apply to digital systems, if you are building low-level analog circuits, and you have a choice between using heat sinks or fans, you will probably be happier with heat sinks.

In 8-bit systems, these precautions may appear to represent overkill, but they reduce time spent in debugging and troubleshooting subtle problems. In so doing, they can pay for themselves. In systems whose resolution is 12 to 16 bits or more, these precautions are mandatory. **EDN**

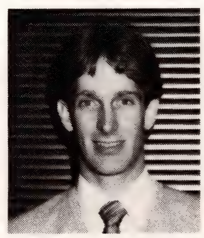
Reference

1. Hamilton, Douglas, and Howard, WG, *Basic Integrated Circuit Engineering*, McGraw-Hill, New York, 1975.

Authors' biographies



Eric Filseth is consulting for Analog Design Tools (Sunnyvale, CA) while he completes the requirements for an MBA at UCLA. He holds a BSEE from Stanford University and was previously employed at National Semiconductor Corp. Eric is a member of the IEEE.



Mike Jachowski is a senior applications engineer at Precision Monolithics Inc (Santa Clara, CA). He has worked at PMI for two years; he previously worked at National Semiconductor Corp and XO Industries. Mike holds a BSEE from the University of Colorado at Boulder and is a co-inventor on one patent. In his spare time, Mike skis and works on building a new home.

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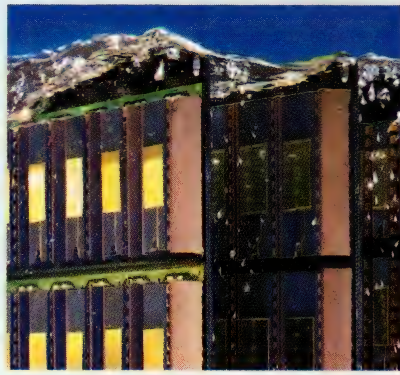

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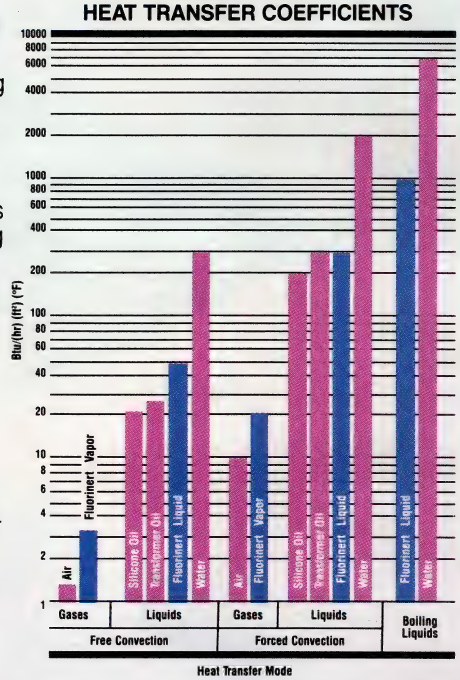
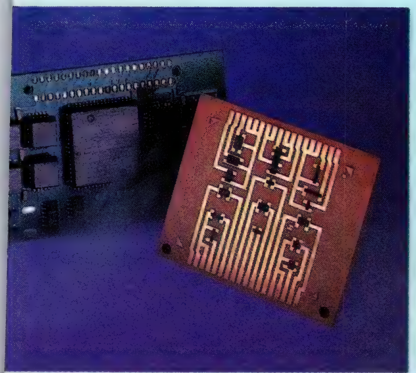
COMPARATIVE HEAT TRANSFER COEFFICIENTS

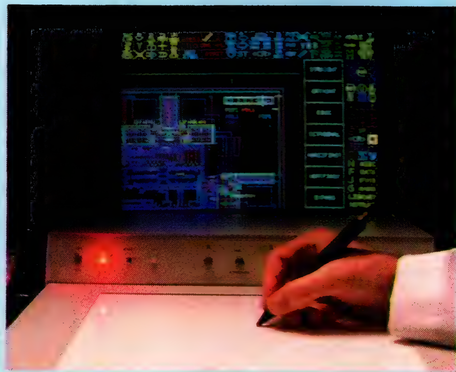


Fluorinert™ Liquids achieve accurate high reliability testing

It's a small world you work in. Where time ticks in nanoseconds and dimension is measured in Angstrom units. And as circuitry becomes more complex, a greater demand is placed on testing capability — not only in speed, but in higher reliability and accuracy.

Fluorinert Liquids meet those requirements by providing a controlled temperature environment and a high degree of electrical protection. They offer maximum compatibility between





the heat transfer medium and the device under test. Fluorinert Liquids reduce testing costs by reducing testing time substantially. They do this by rapidly reaching test temperature and providing precise and uniform temperature control. You'll minimize the number of faulty units by detecting defects before they become rejects.

These liquids provide cost-effective tests such as gross leak, thermal shock, liquid burn-in, ceramic crack detection, electrical environmental, temperature calibration and failure analysis/short detection.

Fluorinert Liquids are specified in the MIL-STD's for thermal shock and gross leak testing.

THERMAL SHOCK TEST CONDITIONS

Military Standard 883-1011			Military Approved Fluorinert Liquids	
Test Condition	**Hot Test Step 1**	**Cold Test Step 2**	**Hot Test Step 1**	**Cold Test Step 2**
A	100°C	−0°C	Water , FC-40	Water , FC-40, FC-77
B	125°C	−55°C	FC-40, FC-70, FC-5311	FC-77
C	150°C	−65°C	FC-40, FC-70, FC-5311	FC-77
D	200°C	−65°C	FC-70, FC-5311	FC-77
E	150°C	−195°C	FC-40, FC-70, FC-5311	Liq. N_2
F	200°C	−195°C	FC-70, FC-5311	Liq. N_2

GROSS LEAK TEST CONDITIONS

Military Standards	Military Approved Fluorinert Liquids		
	Indicator Fluids	**Detector Fluids**	**Absorption Fluids**
MIL-STD 883-1014	FC-40, FC-43	FC-72, FC-84	Do not apply
MIL-STD 750-1071	FC-40, FC-43	FC-72, FC-84	FC-43, FC-75, FC-77
MIL-STD 202-112	FC-40, FC-43	FC-72, FC-84	Do not apply

Discover higher yields in vapor phase soldering

Fluorinert Liquids have been the industry's fluid of choice since the vapor phase reflow soldering (VPS) process was introduced in 1975. There are a number of good reasons for this universal acceptance. VPS with Fluorinert Liquids produces highly reliable solder joints. The system reduces reject rates, increases production, and lowers production costs. With Fluorinert Liquids, you can be assured that your products will never be exposed to a temperature higher than the selected liquid's boiling point. (See above)

You'll avoid those problems usually associated with other systems — shadowing, uneven heating, and overheating. The liquids are non-flammable. Their low surface tension helps them evaporate quickly from the work pieces without leaving a residue.

VPS with Fluorinert Liquids is especially suited for boards with high mass or complex geometries. The liquid vapors completely surround the assembly and penetrate remote recesses to heat all surfaces evenly. The vapors are 15 to 20 times heavier than air so they can be contained easily within the work area. The system offers an oxygen-free, non-corrosive environment to minimize rejects from oxidation contamination.

Some typical applications using Fluorinert Liquids in VPS include surface mounted leaded or leadless components, through-hole leads and wire-wrap pins, lead frame attachment, reflow of electroplated solder or tin and miscellaneous metal joining.

VPS SELECTION GUIDE

Fluorinert Liquid	Boiling Point	Typical Solders
FC-43	174°C/345°F	70 Sn/18 Pb/12 In 100 In 58 Sn/42 In 58 Bi/42 Sn
FC-70, FC-5311 FC-5312	215°C/419°F	63 Sn/37 Pb 60 Sn/40 Pb 62 Sn/36 Pb/2 Ag
FC-71	253°C/487°F	100 Sn 95 Sn/5 Ag 60 Pb/40 Sn

Discover the unique cooling benefits of Fluorinert™ Liquids

As the package size decreases, your need for more efficient heat dissipation increases in proportion. 3M Fluorinert Liquids are very efficient as a direct contact heat transfer medium, with the added advantage of having the high dielectric characteristics needed to meet stringent demands of the diversified electronics industry. We offer 11 liquids with boiling points that range from 56°C to 253°C.

These stable liquids allow you to maximize power density and miniaturize your package. Yet they reduce failure rates and increase reliability.

Fluorinert Liquids are used in such demanding applications as:

- Radar transmitters • Power supplies
- High voltage transformers • Lasers
- Radar klystrons • Computer modules
- Computer memories • Fuel cells

Typical properties of Fluorinert Liquids used in cooling are:

Fluorinert Liquid FC-77 (English Units)	Liquid		Vapor
	Room Temp. (77°F)	**Boiling Point (207°F)**	**Boiling Point 207°F @/ATM**
Density lb./ft^3	111	100	0.85
Thermal Conductivity Btu/(hr) (ft^2) (°F/ft)	0.037	0.033	0.008
Specific Heat Btu/(lb.) (°F)	0.25	0.28	0.23
Viscosity c.p.	1.42	0.46	0.02
Coefficient of Thermal Expansion ft^3/(ft^3) (°F)	0.0008	0.0009	0.0015

Discover heating/curing with Fluorinert™ Liquids

Because they maintain their vapor temperature with absolute precision, Fluorinert Liquids can be used in many heating and/or curing operations. They serve as heat transfer media in solder mask and polymer thick film applications and for polymer processing. The non-corrosive vapors will not support oxidation. Ideal where solvent flash-off is a problem.

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Discover Fluoronics Resources

3M presents a unique short course in the use of Fluorinert™ Liquids for the electronics industry.

3M is now offering a series of "Applied Fluoronics" tapes demonstrating how Fluorinert Liquids are used in a number of applications. See first hand how these remarkable products can improve overall electronic production.

Three cassettes are available:

1. "Applied Fluoronics: High Reliability Testing"
2. "Applied Fluoronics: Vapor Phase Soldering"
3. "Applied Fluoronics: Direct Contact Cooling"

These informative VHS format tapes are available to qualified personnel in the electronics industry. Specify which cassette(s) you would like to view.

Write on your company letterhead, describing your general interest. Mail to: Fluoronics Resources, Industrial Chemical Products Division/3M, Building 223-6SE-04, 3M Center, St. Paul, MN 55144-1000.

For technical information or assistance on High Reliability Testing and Cooling, call 612/733-6282; for Vapor Condensation Heating assistance, call 612/733-7424.

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CIRCLE NO 87

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Without a capacitor, the power supplies or household appliances that you manufacture could cause radio frequency interference. With an unsafe capacitor, they could catch fire.

On average, such a cap has to take more than ten transient attacks a day. Consequently, the self-healing ability is decisive for a long life. But as the number of self-healings increases, so does the risk of breakdowns and short-circuits.

The ability to withstand high voltage transients is measured by a test called First self-healing. This is defined as a voltage drop of 5 V, and is executed periodically at the Rifa Laboratories in Kalmar, Sweden. For years, the outcome of this test has always been the same: 95% of metallized plastic film caps start self-healing at voltages lower than 3 kV; of metallized paper caps made by Rifa, less than five percent.

This test is regarded as a realistic way to quantify the risk of short-circuits. To that, add another aspect. The type of damage that can occur in a plastic cap, resulting in the winding melting or glowing, is a far greater fire hazard than a similar occurrence would be in a paper type cap.

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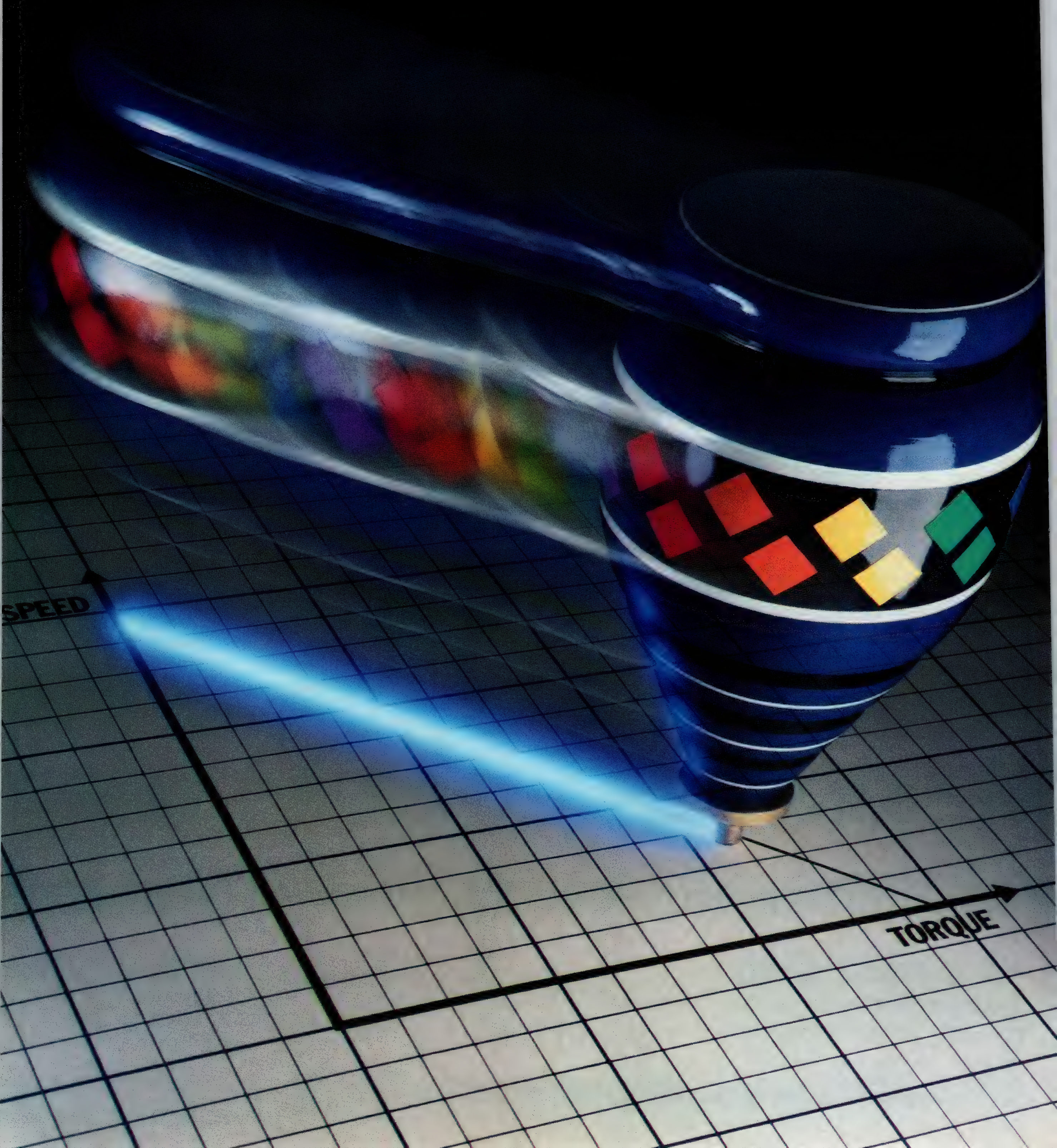

Equivalent circuits model subtle traits of advanced CMOS ICs

Subtle characteristics of an advanced CMOS logic IC's transistors, packaging, bypass capacitor, and load combine to affect the output waveshape. Some of the subtleties are inherent in the IC, but some are under your control. Learning to distinguish among these effects helps you differentiate device types and test and apply the ICs.

Charles Dike, *Signetics Corp*

You can model the outputs of advanced CMOS logic (ACL) as linear LRC networks and gain valuable information about the ICs' ground-bounce and overshoot characteristics. Using these networks, you can also evaluate and improve the test fixtures for the devices. This article compares two quad AND-gate devices: a Fairchild 74AC08 (date code 8619), which has corner-pin connections for V_{CC} and ground; and a Signetics 74AC11008 (date code 8639), which has center-pin V_{CC} and ground connections.

The test setup used to produce the waveform displays for the examples in the text uses a Hewlett-Packard Model HP-54110D digital oscilloscope equipped with 54003-61617 10:1 probes. The displays were produced by routing a screen dump to a plotter.

Switching all outputs together into a standard test load (50 pF in parallel with 500Ω) produced the t_{PHL} and t_{PLH} waveforms in **Fig 1** at the output farthest from the ground pin. This output typically exhibits the highest overshoot of any output. Notice that the outputs ring after switching, and that the ringing is a damped sinusoid in all cases. For both devices, the ringing frequency for the low-to-high transition is slightly lower than that obtained for the high-to-low transition.

Notice also that the center-pin 74AC11008 has less overshoot, its ringing damps out faster, and its ringing frequency—approximately 160 MHz—is higher than that of the 74AC08 (110 MHz). Relating overshoot, damping, and ringing frequency is the key to understanding the differences between the 74AC and 74AC11 families.

Equivalent circuits

Fig 2 models a 2-output ACL device and its test load. Bond wires from the leads of the package connect to the device's silicon die. Each of these leads and bond wires has some amount of inductance. Leads near the end of a DIP have more inductance than leads near the center of the DIP. When the outputs are in a low state, the PMOS transistors appear as an open circuit, and the turned-on NMOS transistors exhibit ~8Ω on-resistance. When the outputs assume a high state, the transistor states are reversed.

A single output in the low state appears in **Fig 3a,** where L_{OUTPUT} represents the output-lead inductance and L_{GND} represents the ground-lead inductance. The

Specifications for the magnitude of overshoot are incomplete without the ringing frequency.

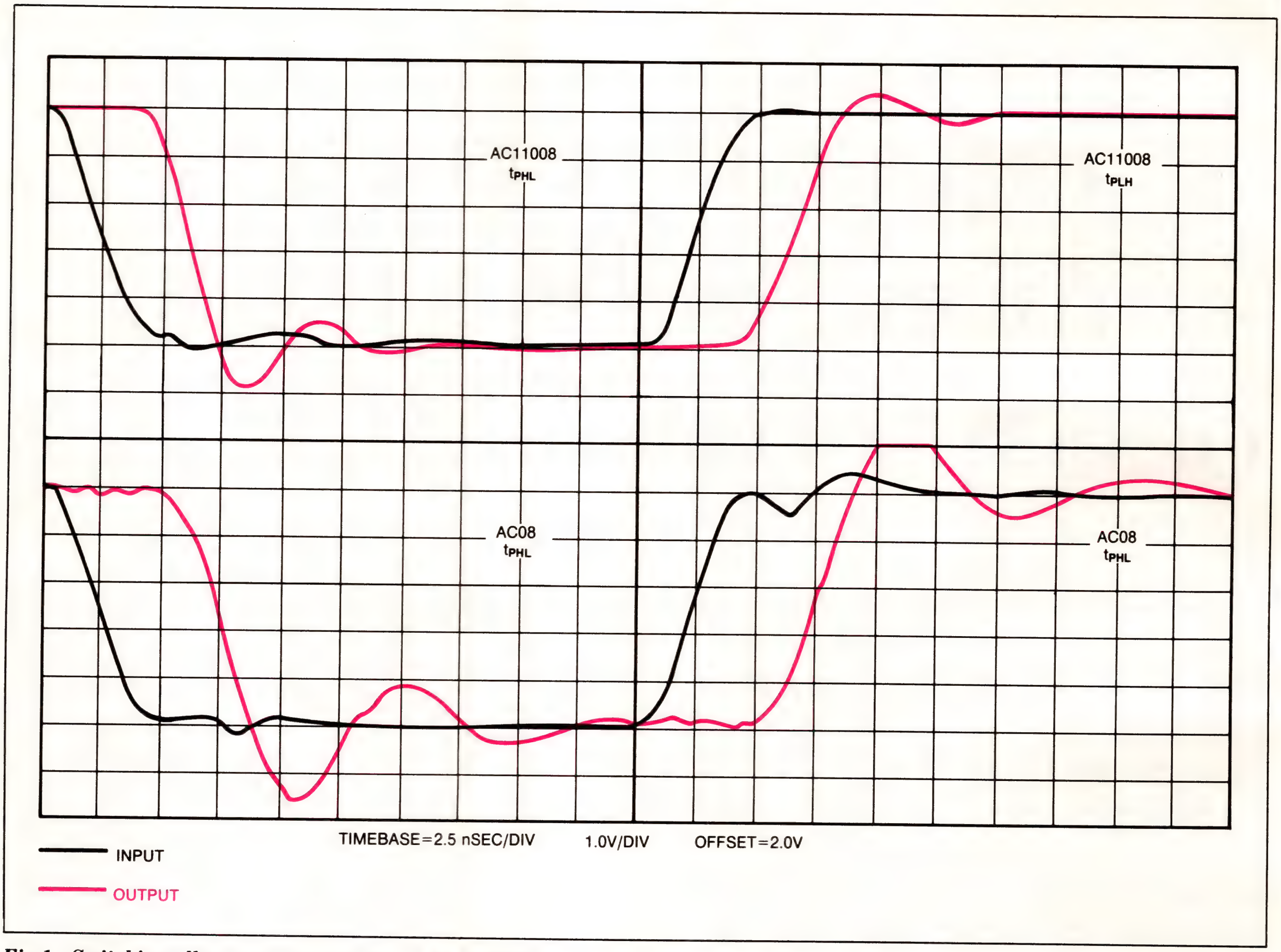

Fig 1—Switching all outputs together into a 50-pF/500Ω load *produced these waveforms at the output farthest from the ground pin (HP 54110 digital scope). Notice that the outputs ring after switching, and that the ringing is a damped sinusoid in all cases. The ringing frequency for the low-to-high transitions is slightly lower than for the high-to-low transitions. The AC08 waveforms show some distortions because of reflections or a noisy ground.*

frequency of oscillation of the center-ground and corner-ground circuits is the same, and calculations show that frequency to be about 205 MHz.

You can convert the circuits of **Fig 3a** to the circuit in **Fig 3b** and write the low-state transfer function as

$$\frac{V_{OUT}}{V_{IN}} = \frac{\frac{1}{LC}}{s^2 + \left(\frac{R_1}{L} + \frac{1}{R_2C}\right)s + \frac{R_1 + R_2}{R_2LC}}. \qquad (1)$$

The form of this equation is the classical

$$\frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}, \qquad (2)$$

where zeta is the damping factor, and ω_N is the natural oscillation frequency. If $R_2 >> R_1$, then

$$\zeta \approx \frac{R_1}{2}\sqrt{\frac{C}{L}} \approx \frac{R_1 C\omega_n}{2} \text{ and } \omega_n \approx \frac{1}{\sqrt{LC}}. \qquad (3)$$

The inverse Laplace transform is

$$V = \frac{R_2\omega_n}{(R_1 + R_2)\sqrt{1 - \zeta^2}} e^{-\zeta\omega_n t} \sin(\omega_n\sqrt{1 - \zeta^2}\, t + \Theta). \qquad (4)$$

This formula describes an exponentially decaying sinusoid—the waveforms of **Fig 1.**

The simple circuits of **Fig 3** do not, however, explain all of the devices' behavioral traits. Because all outputs

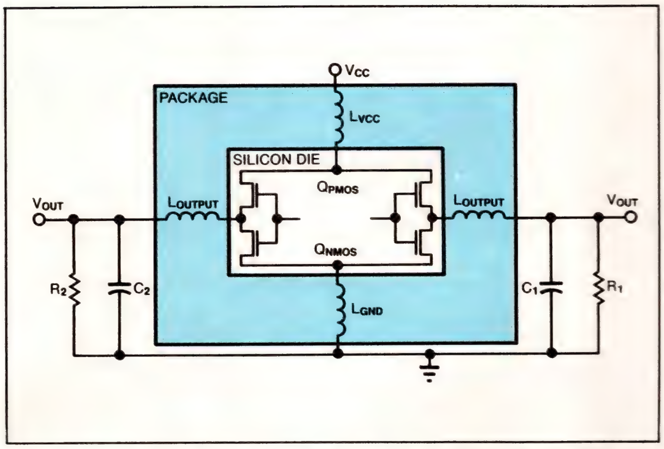

Fig 2—This ACL-device model has two outputs and a test load. *Each of the device's leads and bond wires has some amount of inductance. Leads near the end of a DIP have more inductance than leads near the center of the DIP.*

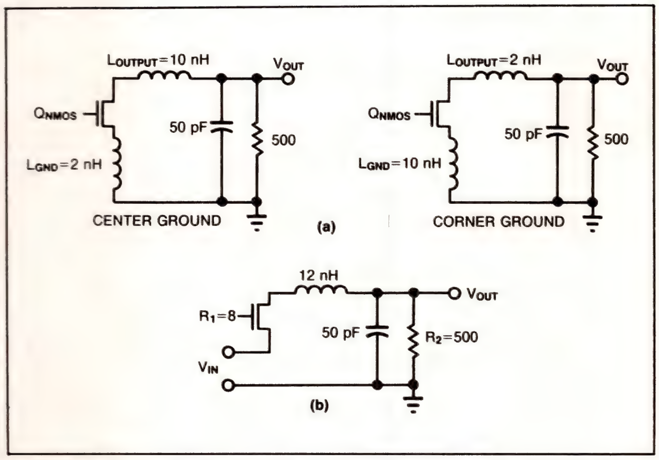

Fig 3—Equivalent circuits for center-ground and corner-ground ICs *show that the equivalent series inductance is the same for both package styles. For single-section operation, therefore, the frequency of oscillation is the same for both.*

in the low state share a common ground inductance, you cannot model them as independent circuits. **Fig 4a** depicts two outputs on a part that has a center-pin ground. The two 8Ω resistors represent the on-resistance of the transistors.

Fig 4b is the Thevenin equivalent of the first circuit. Calculations show that its ringing frequency is about 190 MHz. By extension, **Fig 4c** shows the equivalent circuits for the two quad AND-gate devices. The quad center-ground device rings at about 168 MHz, and the corner-ground device rings at about 110 MHz. Note that as the number of outputs increases, the frequency of oscillation and the total inductance in the circuit decrease.

The high-state circuit is similar to the low-state circuit, but exhibits some interesting differences. **Fig 5a** shows a single high-state tank circuit. C_1 is the bypass capacitor between V_{CC} and ground. **Fig 5b** shows the tank circuit's Thevenin equivalent. This circuit has more inductance than the circuit in **Fig 3** because of the bypass capacitor's inductance (L_{BY}). This added inductance causes the ringing frequency of the low-to-high transition to be lower than that of the high-to-low transition.

The high-state transfer function for this circuit is

$$\frac{V_{OUT}}{V_{IN}} = \frac{R_2C_1\boldsymbol{s}}{(R_2LC_1C_2)\boldsymbol{s}^3+(LC_1+R_1R_2C_1C_2)\boldsymbol{s}^2+(R_2C_1+R_2C_2+R_1C_1)\boldsymbol{s}+1}, \tag{5}$$

but because in this case

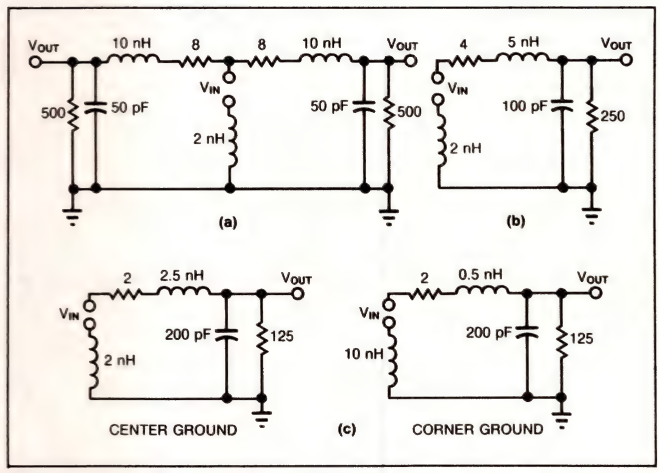

Fig 4—The simple circuits of Fig 3 *do not explain all of the devices' characteristics. Because all outputs in the low state share a common ground inductance, you cannot model them as independent circuits. In* ***a****, you see two outputs on a part that has a center-pin ground. The two 8Ω resistors represent the on-resistance of the transistors;* ***b*** *is the Thevenin equivalent of the circuit in* ***a****. Finally,* ***c*** *shows the equivalent circuits for quad AND-gate devices.*

$LC_1 << R_1R_2C_1C_2$ and $R_2C_2 << R_2C_1 + R_1C_1$

$$\frac{V_{OUT}}{V_{IN}} \approx \frac{R_2\boldsymbol{s}}{(R_2LC_2)\boldsymbol{s}^3 + R_1R_2C_2\boldsymbol{s}^2 + (R_2 + R_1)\boldsymbol{s} + \dfrac{1}{C_1}} \tag{6}$$

or

$$\frac{V_{OUT}}{V_{IN}} \approx \frac{\dfrac{\boldsymbol{s}}{LC_2}}{\boldsymbol{s}^3 + \left(\dfrac{R_1}{L}\right)\boldsymbol{s}^2 + \left(\dfrac{R_2 + R_1}{R_2LC_2}\right)\boldsymbol{s} + \dfrac{1}{R_2LC_2C_1}}, \tag{7}$$

Relating overshoot, damping, and ringing frequency is the key to understanding the differences between the 74AC and 74AC11 families.

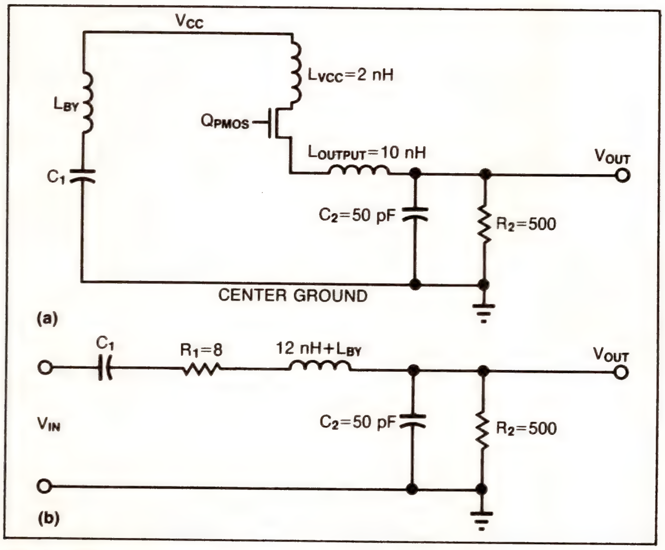

***Fig 5—The high-state circuit is similar to the low-state circuit of Fig 3,** but includes the device-bypass capacitors. The added inductance of the bypass capacitors lowers the ringing frequency.*

the form of this equation is

$$\frac{As}{s^3 + 2\zeta\omega_o s^2 + \omega_0^2 s + B}, \quad (8)$$

where zeta is again the damping factor, ω_O is the frequency of the damped oscillations, and A and B are scale factors. Again,

$$\zeta \approx \frac{R_1}{2}\sqrt{\frac{C}{L}} \text{ and } \omega_O \approx \frac{1}{\sqrt{LC}}. \quad (9)$$

From the preceding math, you can see that the bypass capacitor does not significantly affect either the frequency of oscillation or the damping, provided that it's much larger than the load capacitance. However, the inductance of this capacitor can add considerably to the overall loop inductance.

For a center-pin configuration, the V_{CC} and ground pins are 300 mils apart for any size DIP. On a corner-pin part, the V_{CC} and ground pins are a minimum of 670 mils apart for a 14-pin DIP. Although you might expect a ground plane to eliminate the greater lead inductance of a capacitor that must span the corner-pin device's larger spacing, in fact, the ground plane has inductance between any two points. **Eq 1** makes it clear that minimizing inductance increases damping and reduces ringing amplitude.

All outputs on a part are interdependent. This interdependency causes ringing in unswitched outputs. In

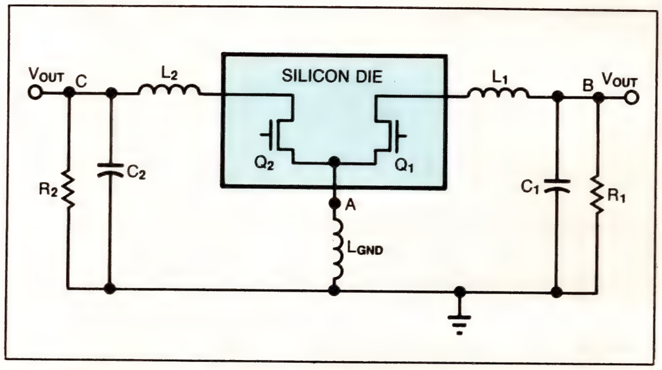

***Fig 6—Switching one output causes ringing** in unswitched outputs. If Q_2 is on and Q_1 turns on, current flow from C_1 will raise the voltage at node A. This rise, in turn, will force current into C_2, initiating ringing.*

Fig 6, assume that Q_1 has just turned on and that node B is still at 5V. Also, assume that Q_2 has been on for some time, so that node C is at 0V. Q_2 drives the unswitched output.

As current begins to flow from C_1 (at node B) through L_1, Q_1, and L_{GND}, node A's voltage begins to rise and node B's begins to drop. The rise in node A's voltage causes current to flow from node A through Q_2 and L_2 into C_2. The voltage at node C then rises above ground.

As the voltage at node B drops, the rate of change of current through Q_1 stops increasing and begins to decrease. This decrease causes the voltage at node A to reverse polarity and begin to draw current from C_2. Because node A goes negative with respect to ground, nodes C and B will follow. Eventually, the rate of change of current reverses yet again, and this cycle continues until the circuit resistances dissipate all the energy stored in the inductors and capacitors.

Ground bounce

When more outputs switch in parallel with Q_1, the rate of change of current increases and the voltage at node A rises, and this rise causes the voltage at node C to rise. The outcome is that more energy is stored in storage elements, causing the overshoots to be higher and the system to ring longer. How can the overshoot be reduced? One way to make L_{GND} as small as possible is to use the center-pinout configuration.

Fig 7 displays the worst-case ringing at the unswitched output that occurs when all other outputs are switching high to low.

In addition to the mechanism described in the preceding section, another mechanism contributes to overshoot in unswitched outputs. That mechanism is mutual inductance. In **Fig 6**, mutual inductance between L_1 and

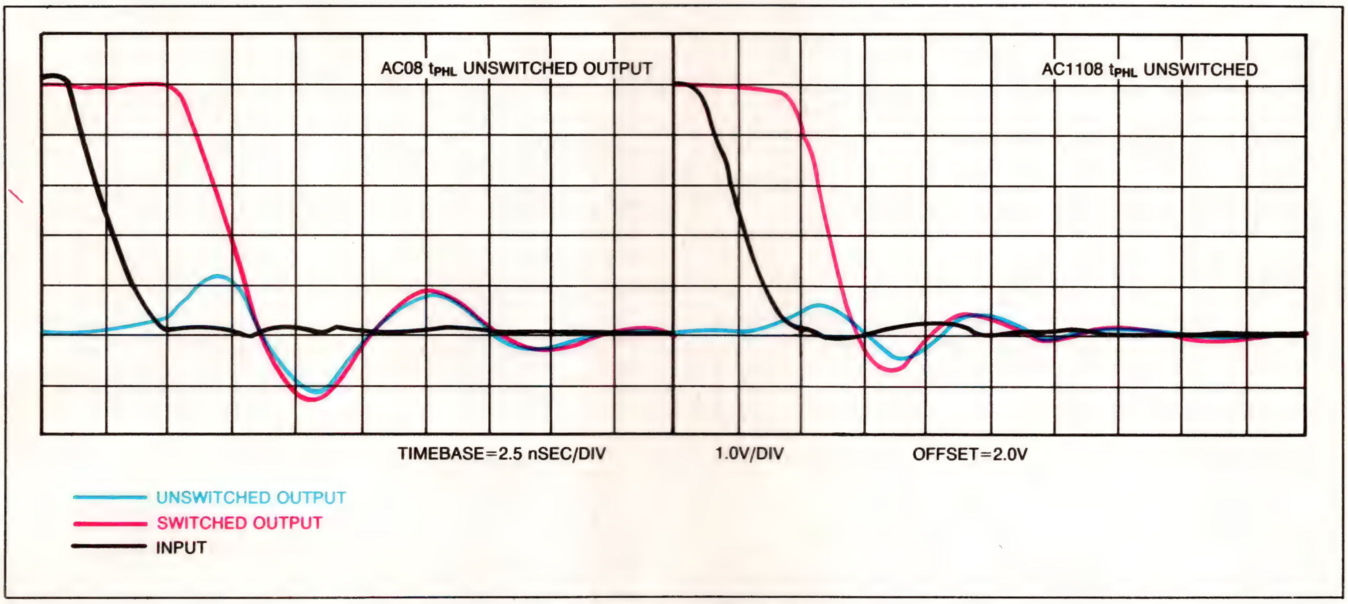

***Fig 7—Switching all other outputs high to low** produces the worst-case unswitched-output ringing. Observe that the initial bounce is lower for the AC11008 than for the AC08.*

L_2 couples energy from one inductor to the other during the transition. This coupling affects the overshoot. The magnitude of the effect depends on the proximity of L_1 to L_2, and the polarity of the effect depends on the relative direction of the change of current through the output pins. The unswitched output will be affected most if it is adjacent to a switched output that has a high current slew rate.

In real applications, additional factors complicate the simple models in **Figs 2** to **6**. For example, the simple models assume that all output-pin inductances are the same. In fact, the output-pin inductances for a 16-pin DIP can vary from ~3 to ~10 nH.

As long as all outputs switch simultaneously and in the same direction and end up in the same state (either low or high), then they will ring at nearly the same frequency—each output rings at a frequency within ~10% of the highest frequency. This frequency is the package's ringing frequency. However, because each output pin's inductance is different, each one stores a different amount of energy. This difference causes the outputs that have the largest inductances to ring to higher amplitudes.

Another complication occurs when one or more outputs remain high while the rest switch to a low state. For a short interval, an output in transition has both its lower and upper output transistors turned on simultaneously. This condition causes a current to pass through the V_{CC} inductance, both transistors, and the ground inductance.

Because the V_{CC} inductance stores this energy, it must be dissipated in a tank circuit similar to the circuit in **Fig 5**, and ringing occurs on the unswitched high output because of a high-to-low transition. Again, the switched-output circuit is similar to the circuit in **Fig 3.** These circuits have no common elements (except mutual inductance), so they can ring at different frequencies. These frequencies depend, in a complex manner, on which outputs remain high and which outputs switch. And they usually will be higher than the package-determined ringing frequency. (Although the examples have dealt with outputs switching high-to-low, the same logic applies to low-to-high transitions.)

Compare measurements and models

Whatever the cause of the ringing, any ringing-output waveform should display an essentially pure, exponentially damped sinusoidal shape. This shape should be independent of the ringing frequency, but the damping should increase with the ringing frequency. **Fig 8** overlays calculated and measured curves. Note that the initial peak of the model does not reach the initial voltage of the measured data. This discrepancy arises because the formulas rely on a constant-resistance model for the transistor. This model can be far from accurate when the voltage across the transistor exceeds a couple of volts or when the transistor is turning on. In actual practice, both situations apply.

Because all outputs in the low state share a common ground inductance, you cannot model them as independent circuits.

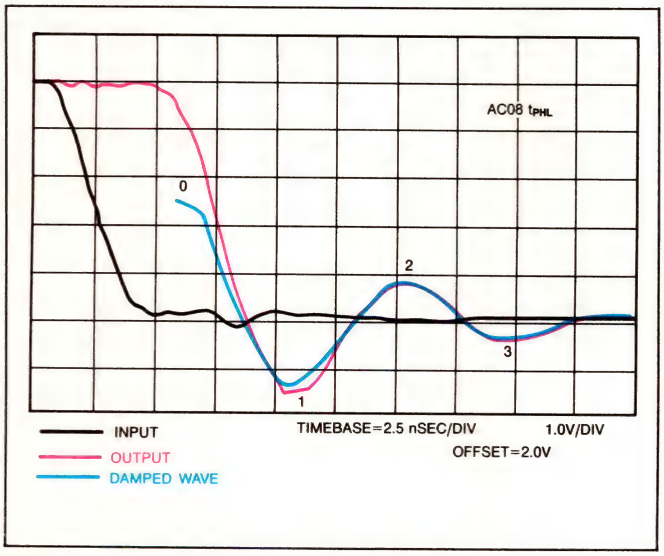

***Fig 8—Overlaying the calculated and actual curves** reveals that the initial peak of the model's prediction does not reach the initial voltage of the measured data. This discrepancy arises because the formulas rely on a constant-resistance model for the transistor.*

These situations do not last long (until V_{OUT} reaches about 2.5V) before the circuit approximates the constant-resistance model.

The formula for zeta **(Eq 1)** states that for a fixed capacitance, increasing the resistance or reducing the inductance will increase the damping factor. This increase, in turn, reduces the overshoot. Zeta has a greater sensitivity to changes in R_1 than it has to changes in L. However, because ACL outputs must maintain a V_{OL} of 0.5V over a wide range of temperatures and power-supply voltages while sinking 24 mA, device designers fix the individual transistor resistance (at room temperature and V_{CC}=5V) at about 8Ω.

For the center-pin quad-AND device in a DIP, our target zeta result is

$$\zeta = \frac{8}{2(4)}\sqrt{\frac{0.2}{4.1}} = 0.221, \qquad (10)$$

for approximately 49% overshoot. The 4.1-nH value is from **Table 1.** The 4 in the denominator represents four outputs. For the corner-pin package, zeta equals 0.150 (for ~62% overshoot). A side benefit of reducing the inductance is that the edge rates increase. This increase, in turn, yields somewhat shorter propagation delays.

Another way to reduce overshoot is to slow down the turn-on of the transistor and the edge rate. This slow-down, in turn, lengthens the propagation delay. All producers of ACL use this approach to control overshoot when simultaneous-switching problems arise; however, products that have reduced inductance can employ this approach more effectively.

At low temperatures, the overshoot will increase for two basic reasons. First, the resistance of the turned-on transistor is lower, thereby causing zeta to decrease. Second, the signal at the gate of the transistor switches more rapidly, thereby causing the transistor to turn on faster. The ringing frequency over temperature, however, will remain the same except for small variations caused by changing damping considerations.

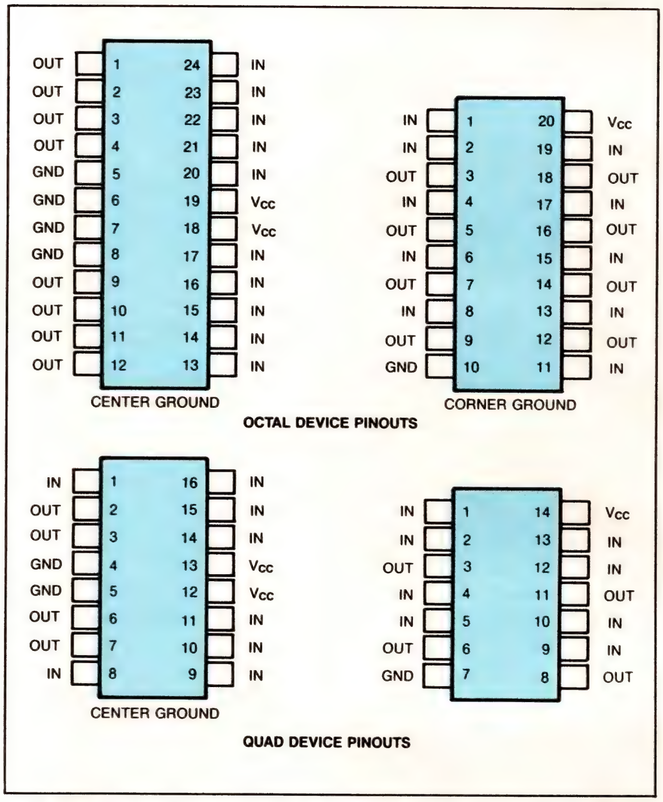

***Fig 9—These pinouts are used to obtain** the inductances in **Table 1.** The packages shown reflect the industry-standard pinouts for octal and quad logic families.*

TABLE 1—PACKAGE LOOP INDUCTANCE

	OCTAL DIP 300 MIL	QUAD DIP 300 MIL	OCTAL SO 300 MIL	QUAD SO 300 MIL	QUAD SO 150 MIL
CORNER	13.1 nH	8.9 nH	8.2 nH	6.4 nH	4.1 nH
CENTER	4.4 nH	4.1 nH	2.8 nH	3.0 nH	2.1 nH

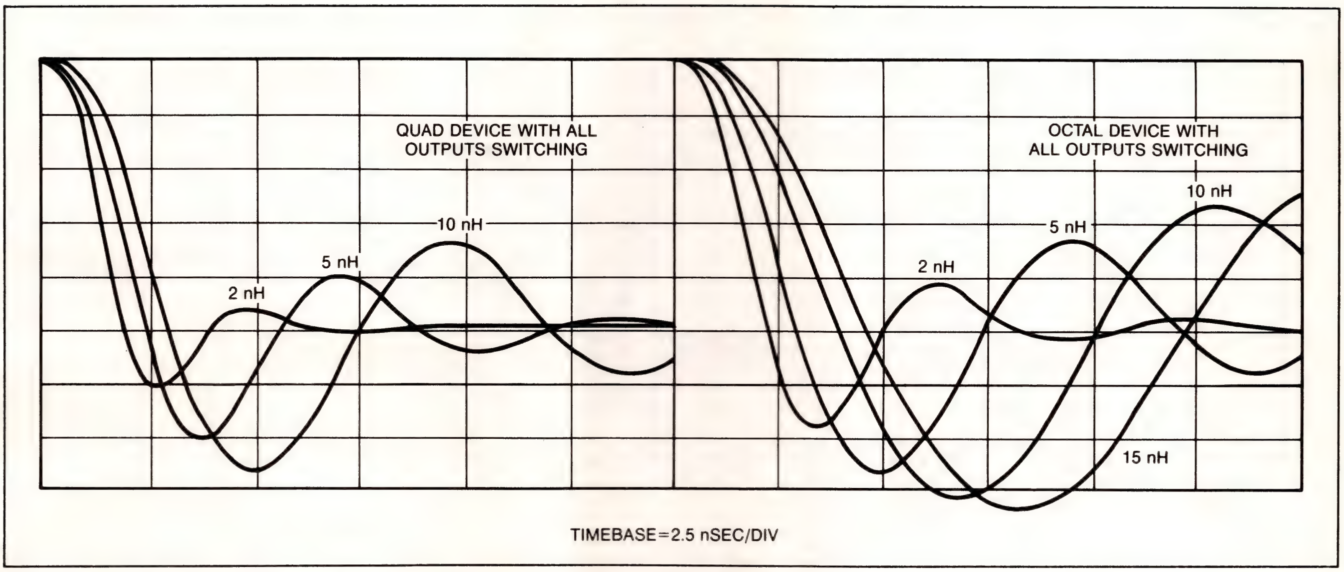

Fig 10—Quad and octal devices exhibit differing inductances. *These inductance differences translate to variations in the ringing frequencies.*

The primary problem in testing products is that the characteristics of both the device under test (DUT) and the test fixture (including the measurement system) influence the measurements taken. Armed with the results of the simple models given here and keeping in mind the additional complicating factors, you will be able to separate the DUT's performance from artifacts introduced by the test fixture.

To correlate information obtained from differing test fixtures, you must be able to somehow compensate for their differences. **Table 1** shows the inductances derived from simulations of various packages on an idealized test fixture that has 50-pF capacitors on each output. The idealized setup has no parasitic capacitances, a zero-resistance current path (except for the 500Ω resistor in each load and the transistors' on-resistances), and no spurious inductive coupling. **Fig 9** shows the pinouts used to obtain the inductances given in **Table 1**.

The output pins that have the lowest individual output-lead inductance will ring at the idealized package ringing frequency, whereas those that have the highest inductance will tend to ring at about a 10% lower frequency. **Table 2** shows that the center-pin configuration can ring at about a 50% higher frequency than the corner-pin configuration; consequently, the center-pin part will have less overshoot, which will damp out faster than will the overshoot for the corner-pin part. Measurements taken on octal DIP parts have shown that the idealized package ringing frequency,

TABLE 2—IDEAL PACKAGE RINGING FREQUENCY

	OCTAL DIP 300 MIL	QUAD DIP 300 MIL	OCTAL SO 300 MIL	QUAD SO 300 MIL	QUAD SO 150 MIL
CORNER	70 MHZ	119 MHZ	88 MHZ	140 MHZ	176 MHZ
CENTER	120 MHZ	176 MHZ	150 MHZ	205 MHZ	246 MHZ

based on the simple model, is optimistic. The center-pin octal part rings at about 100 MHz, and the corner-pin octal part rings at about 50 MHz.

Less-than-optimal tests

Several things contribute to the existence of less-than-optimal conditions on a test fixture—some you can address, others you cannot. The ringing frequency and waveshape considerations combine to provide a tool that will allow you to improve your test fixture and to correlate your measurements with measurements made on other test fixtures.

Many test fixtures are universal designs in which the load is located some distance from the device under test. This distance allows you to modify the load by using shorting strips, and to adapt the test fixture to a variety of package widths. This adaptability provides a reasonable way to minimize incoming-inspection costs if you recognize the tradeoffs. Because the load is not as close as it could be to the device under test, inductance

All outputs on a part are interdependent. This interdependency causes ringing in unswitched outputs.

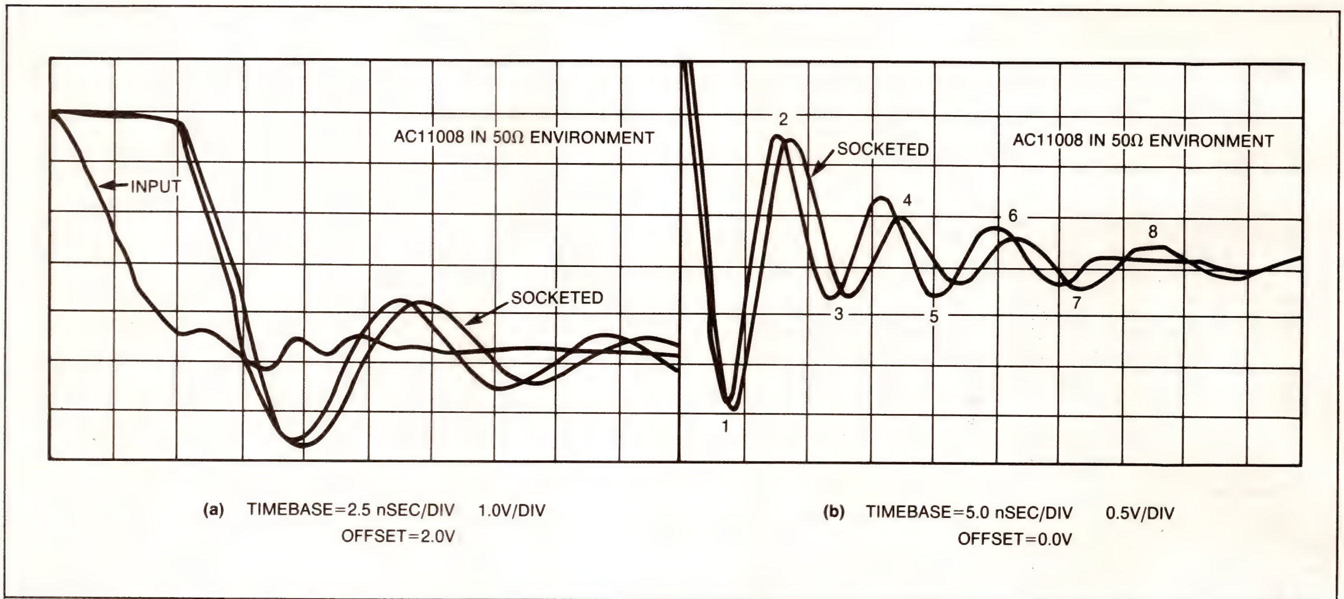

***Fig 11—Adding a socket to a test setup** alters device waveforms adversely. Propagation time and overshoot increase, and the ringing frequency decreases.*

increases. **Fig 10** shows the ringing waveforms of a quad device and an octal device that have different inductances.

A quick review of **Fig 8** shows that the quad device's 10-nH waveform (~110 MHz) in **Fig 10** is an excellent representation of the ringing of the 74AC08, and the quad device's 5-nH waveform (~150 MHz) matches reasonably well with that of the 74AC11008. The 74AC11008 deviates from the model's prediction because it has an on-resistance of 6.5Ω—instead of 8Ω—per transistor. The package ringing frequency of the 74AC11008 is 160 MHz instead of 150 MHz.

Specifications for the magnitude of overshoot are incomplete without the ringing frequency. The following formula shows the relationship between damping and the percent of overshoot (PO):

$$PO = 100 \exp\left(\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}\right). \tag{11}$$

But, of course, damping is also a function of frequency. The formula describes the percentage by which point 1 of **Fig 8** overshoots the ground when falling from point 0; unfortunately for correlation purposes, as the frequency of oscillation increases, point 0 tends to fall. The amount point 0 falls is a function of the output-circuit design—a factor beyond your control.

Fig 11a demonstrates the effects of changing inductance on an AC11008 measured on a 50Ω-impedance test fixture. To increase inductance, a low-profile socket was added to the test fixture. Immediately obvious are the ~250-psec increase in the propagation time and the lower ringing frequency of the socketed device. The amplitude of the first overshoot is greater than that of the unsocketed device. This result also meets our expectations.

But, you might ask, where is the exponential decay? Because the frequency is ~120 MHz, the inductance must be ~8.8 nH. This inductance, in turn, fixes zeta at ~0.122 (R=6.5Ω), a figure that indicates the overshoot should be near 65%. But from point 1 to point 2 of **Fig 10b,** the overshoot is nearly 85%. This amount of overshoot is not physically possible from the device alone, and demonstrates a test-fixture problem. Something related to the test fixture is causing either the effective ground to shift, or the overshoot's amplitude to be distorted. At any rate, the overshoot measurements are not reliable.

Further investigation of **Fig 11b's** extended waveform shows that points 3 and 6 have the same height, and point 8 is missing on the unsocketed device—a sign of more signal corruption by the test fixture. Test fixtures that have a large amount of distributed capacitance develop spurious, contaminating tank circuits whose responses beat against the output signals in a complex manner. The differences between the two signals—not far removed in frequency—in **Fig 11** demonstrate this effect. To ensure signal integrity, you

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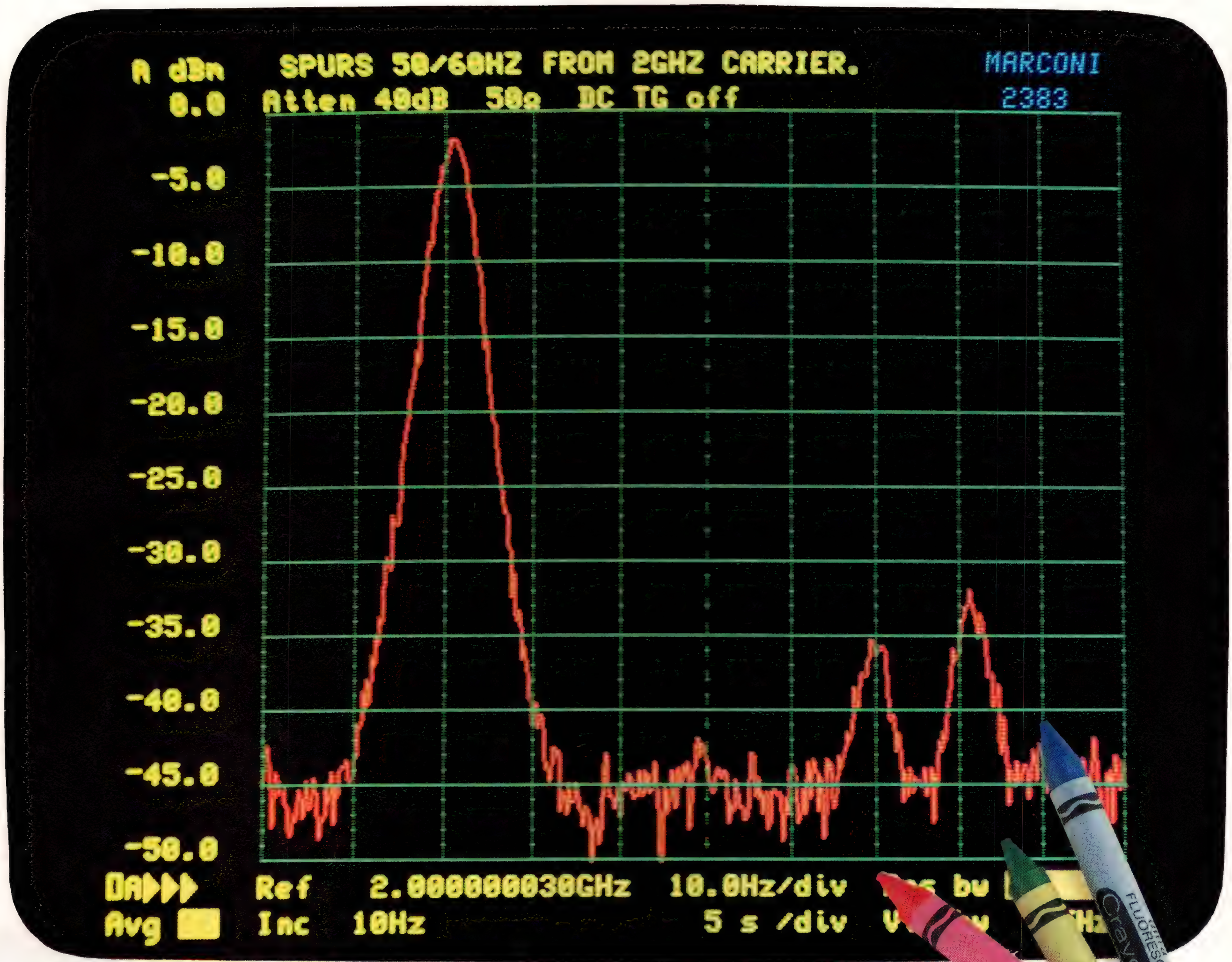

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One way to make the DIP's lead inductance as small as possible is to use the center-pinout configuration.

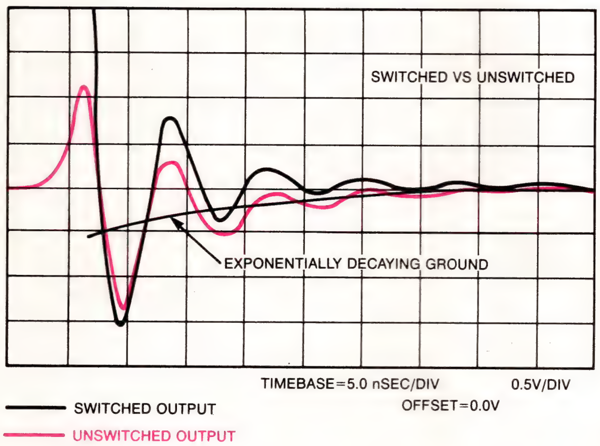


***Fig 12—A miscalibrated high-impedance probe** can also distort output waveforms—in this case, it introduces an exponentially decaying ground reference.*

must reduce distributed capacitance in the load until the output of the device under test rings in a damped sinusoidal pattern.

In addition to frequency considerations, you should address distortions arising from reflections or a noisy ground. These distortions are more likely to occur on a test fixture that has higher inductances. Distortions can show up in even the best corner-pin packages. The AC08 waveforms in **Fig 1** show some distortions on the sinusoidal waveform because of this problem.

Further test-fixture clues

You can gain further insight into the effectiveness of your measurement system by comparing a switched output to an unswitched output. When an output switches from high to low, the induced ringing should be centered about the ground. Any offset from ground indicates a problem in the measurement system. This problem could be a simple dc offset, an exponential-curve distortion (arising from improperly calibrated test probes), superimposed noise from the test-equipment power supplies, or perhaps other problems.

Although it is beyond the scope of this article to address these problems, a simple calibration aid can determine whether any of these problems exist. Simply switching three outputs of an AC11008 high to low, for example, while holding one low, will uncover the problem. Because the unswitched output has no dc component, it rings about ground when the switched outputs change. But the switched outputs change their dc component drastically, and can cause an offset from ground that decays exponentially toward ground. This effect is probably the problem in **Fig 11,** where the 50Ω environment is excessively capacitive, as well as in **Fig 12**, where a high-impedance probe is excessively inductive.

Figure of merit

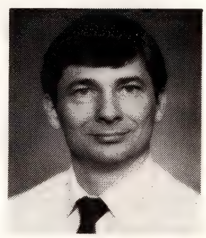
Any system that produces a clean, exponentially damped sinusoidal output waveform that oscillates about ground when all the outputs are simultaneously switched high to low should produce problem-free output waveforms under any conditions. The oscillation-characteristics data you collect for the outputs of an ACL device will prove useful for determining how optimal a test fixture is for other product families—for instance, bipolar devices. A test fixture optimized for ACL-family devices is also optimized for high-speed bipolar devices. **EDN**

Acknowledgment

This article is based on a study of ACL output characteristics completed by Edward A (Ted) Burton and the author. A package-modeling program written by Dr Robert C Burton calculated the inductances. The author could not have written this article without their contributions.

Author's biography

Charles E Dike is a senior design engineer for Signetics Corp in Orem, UT. He has been with his present employer for 10 years. He obtained a BSEE and MSEE at Brigham Young University. In his spare time he enjoys reading and skiing.



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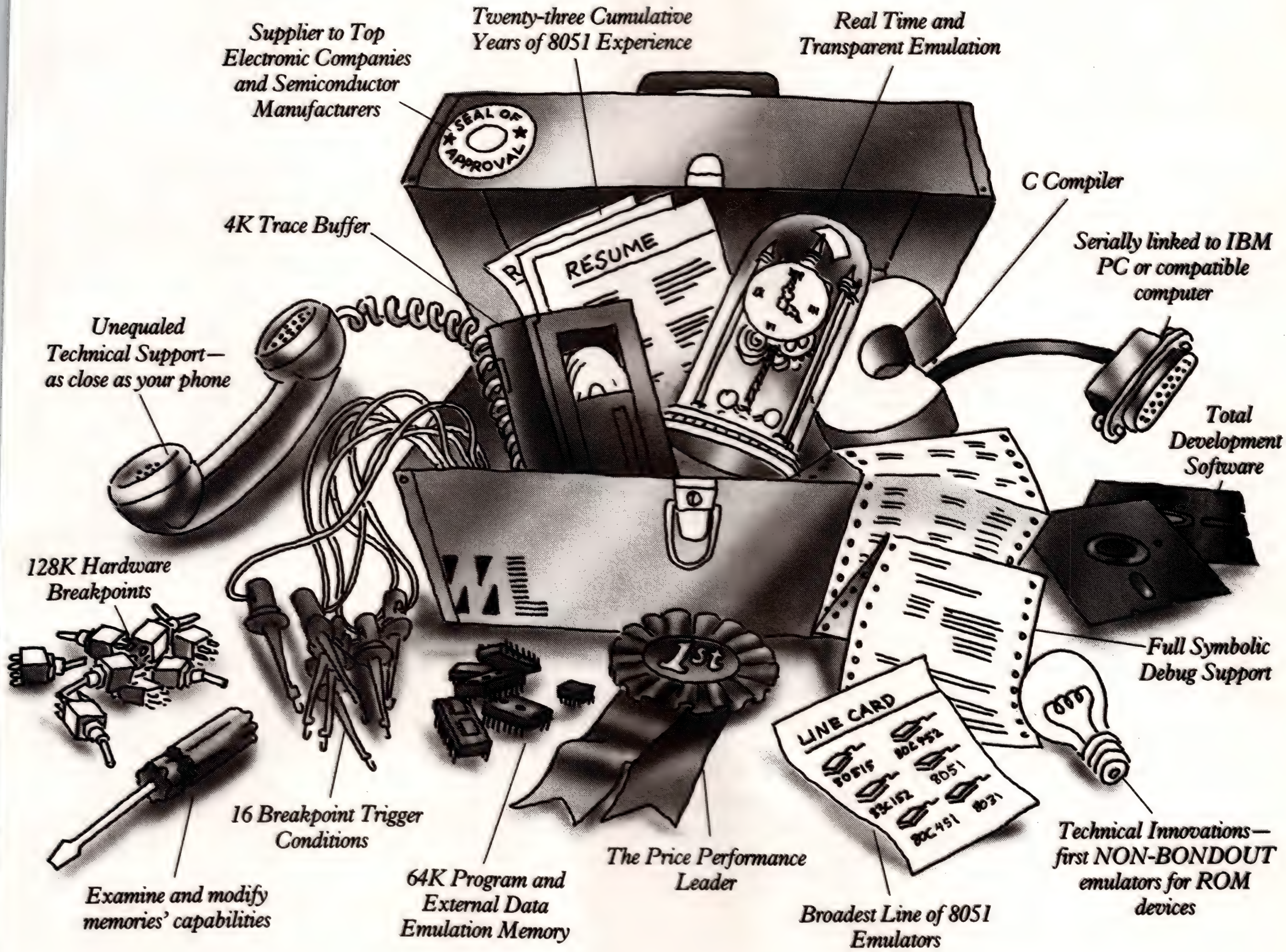

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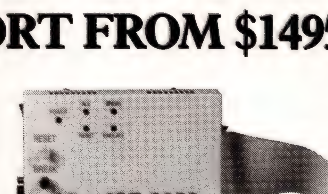

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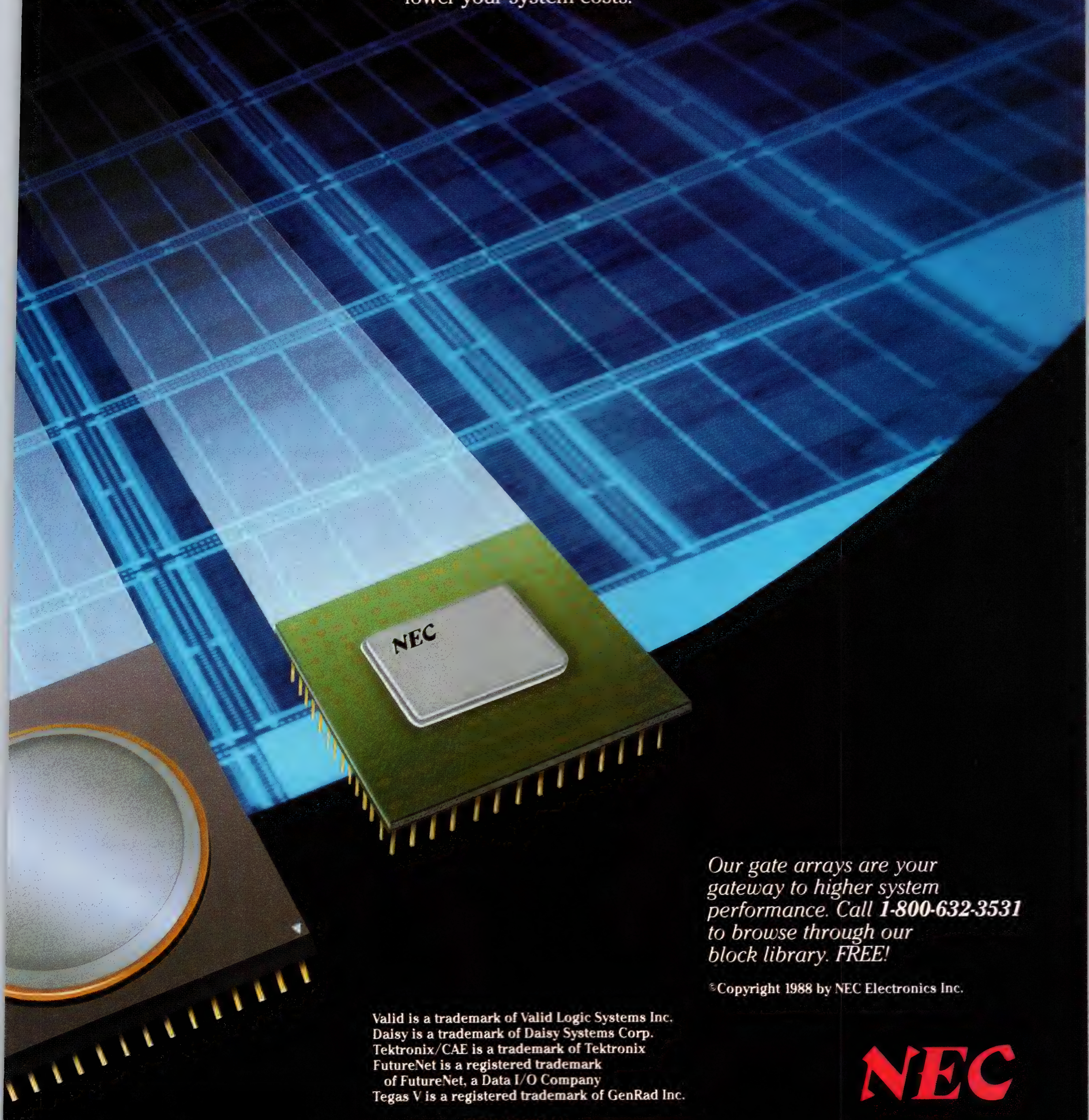

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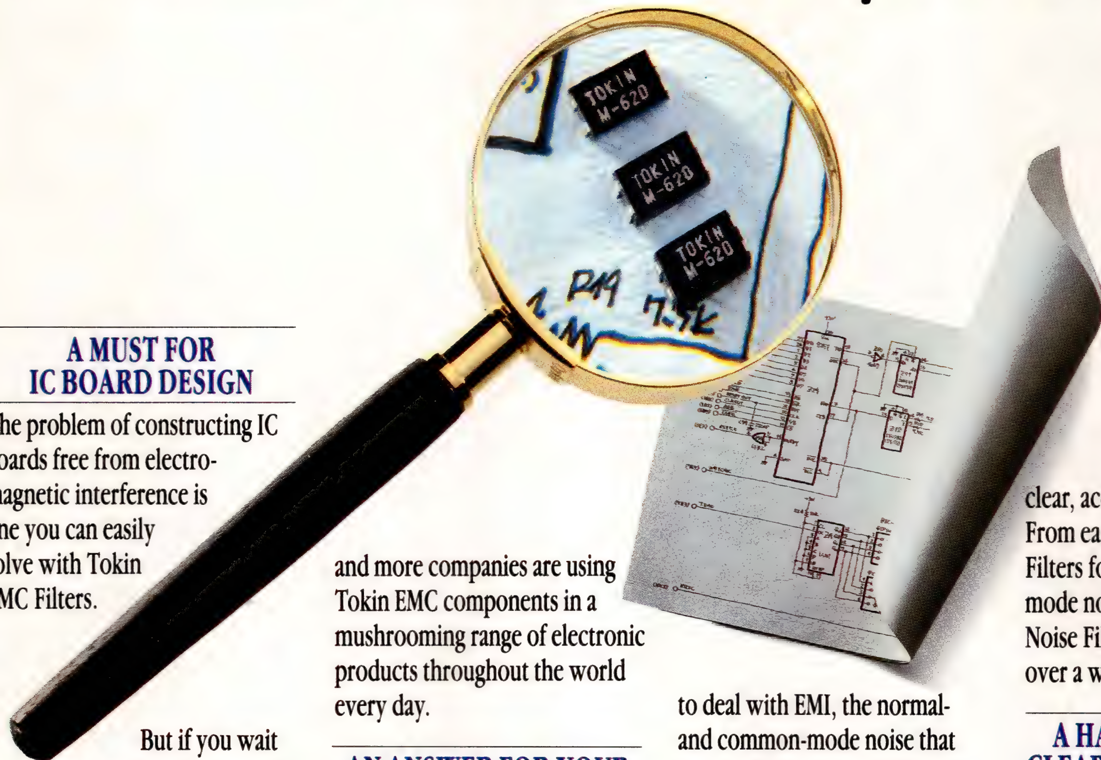

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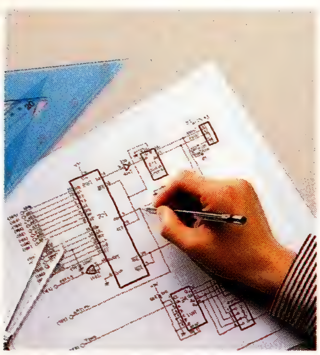

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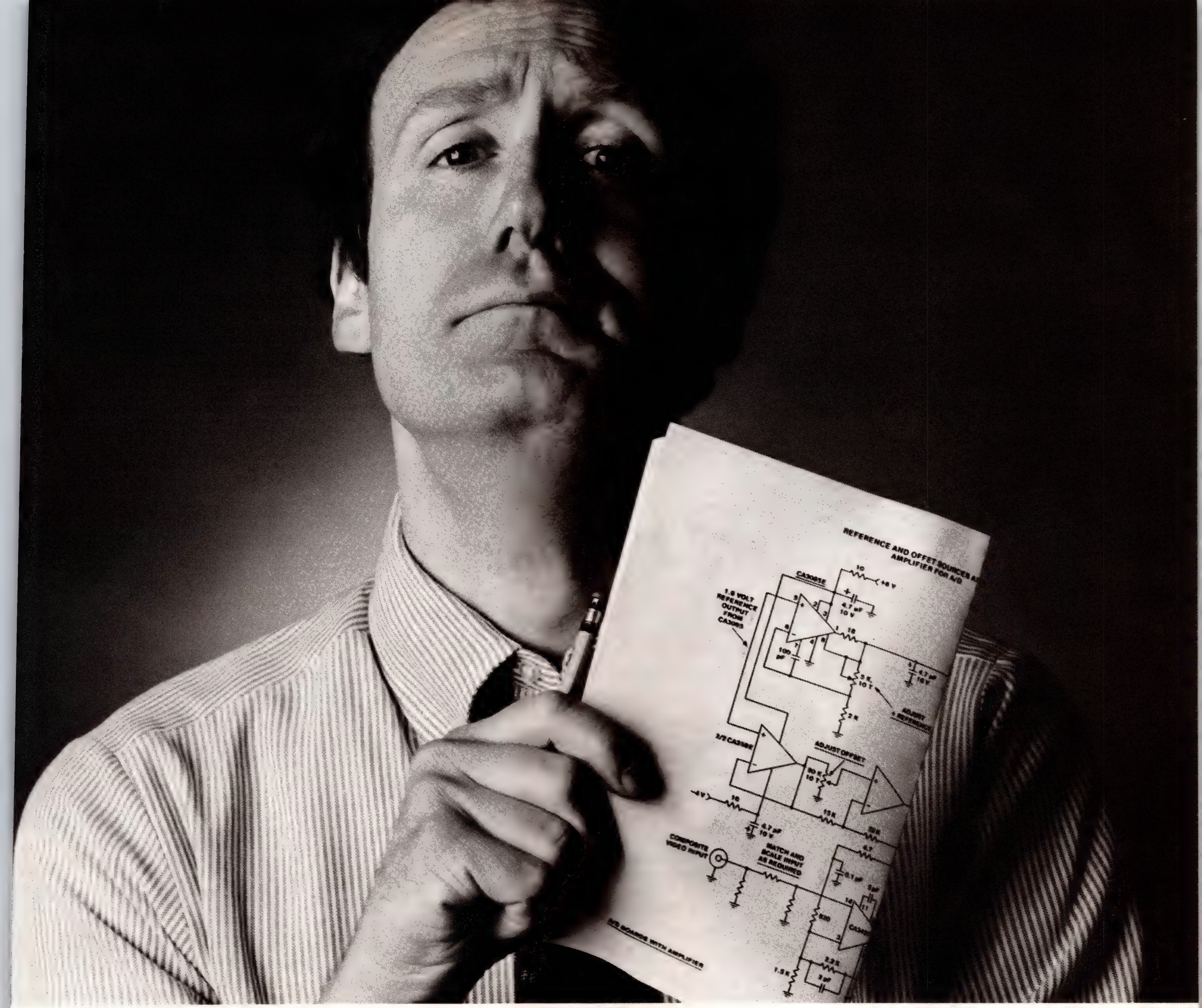

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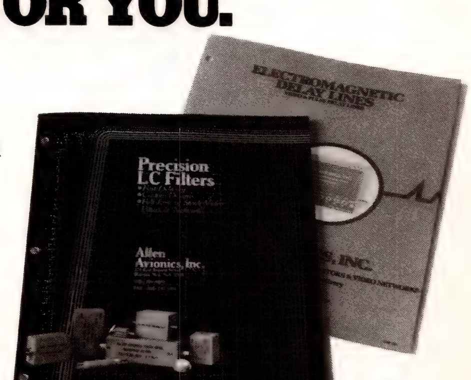

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Dynamic testing describes behavior of high-frequency ADCs

Conventional dc testing cannot fully describe the behavior of high-speed ADC systems—particularly when the input frequency approaches one-half the sampling rate. Using improved dynamic-testing methods, you can accurately characterize the performance of an A/D converter that is operating near its theoretical limits.

Eric D Blom, *Sipex Corp*

High-speed A/D-conversion systems require dynamic testing to quantify their performance. Conventional dc testing is incapable of providing useful information relative to the performance of an A/D system at high frequencies. The problem becomes particularly acute when the components of the input signal approach, or exceed, one-half the sampling frequency. Even when dynamic specifications are provided, they are not always useful—manufacturers have not standardized on the tests or methods used, partly because many tests are necessary only for certain applications. Moreover, most dynamic specifications don't tell the whole story about the types of degradation that arise when you push input power bandwidths to the limit. The dynamic-testing system described here uncovers the actual performance of some common flash converters. The results of the tests yield specifications that more fully describe the actual behavior of a digitizer operating near its theoretical speed limit.

The thrust of technology has made available A/D converters that are capable of very high sampling rates. These high rates make possible the multiplexing of an ever-increasing number of channels at a given effective sampling rate, or, alternatively, the digitizing of wide-band single channels at higher sampling rates. In either case, the use of high-speed A/D converters is often disappointing unless you fully understand their dynamic specifications.

In general, you should consider the dc specifications of a converter's linearity as the best-case limit on its dynamic performance. You can normalize the most useful dynamic specifications into numbers that are measurable with dc tests; in these cases, you can compare the degradation at a specific (high) frequency to the best-case-dc, or low-frequency, numbers. Unfortunately, only the best flash converters degrade gradually and gracefully in performance as you increase the large-amplitude input-signal frequency. If the input signal contains appreciable power at frequencies near the Nyquist limit, a careful study of the converter's dynamic specifications and an understanding of the converter's architecture are necessary to predict the type of degradation you will encounter.

When sampling a high-slew-rate signal, many flash converters exhibit a phenomenon known as spurious codes. Consider the flash architecture of **Fig 1**, where the input signal couples directly to all 255 comparators. Each comparator exhibits a propagation delay, which is the time between the application of voltage overdrive at

Many flash converters exhibit a phenomenon known as spurious codes when sampling a signal that has a high slew rate.

the input and the change of state at the output. A classic synchronization problem arises when the comparator-bank output is sampled while the output is changing state. This problem is compounded if the propagation times through the comparators are not exactly equal.

Assume comparator 128 of **Fig 1** has a t_{pd} (total propagation delay) that's 60 psec faster than that of comparators 127 and 126. When a fast-slewing input signal is present at the input, the output of comparator 128 will show a logic One for a period as long as 60 psec before the other two comparators switch to logic One. If the comparators' outputs are sampled (latched) during this time, then the normal thermometer-code output of these latches (all Ones continuing to a certain comparator, then all Zeros above that comparator) will show a double bubble. The bubble will appear for the full 60 psec if the input slew rate is infinite. The bubble will not appear at all if the input signal requires 60 psec to slew from the comparator voltage at 126 to the comparator voltage at 128.

The encoding circuit will assign this illegal input to some output code—a correct code if sufficient redundancy exists in the encoder logic, or some other code determined by the don't-care state used in the Boolean-logic minimization of the encoder design. Early converters often mapped these illegal inputs to code 255, resulting in an output code of 255 for an input somewhere near mid-scale.

In the general case, in which the converter is digitizing an input of unknown phase or timing, spurious codes caused by this slew-related phenomenon arise in a random fashion. The converter will generate a spurious code only if the latch command occurs during the 60-psec double bubble. Thus, the probability of a spurious code's occurrence is related to how often the comparators are sampled during this time window; the probability is the ratio of the time duration of the bubble to the period of the sampling clock. A sample/hold synchronizer, or an input multiplexer that's timed to slew near this sampling point, can actually increase the probability of error occurrence.

Early attempts to quantify this spurious-code phenomenon led one manufacturer of CMOS flash converters to include a *sparkle* specification. When viewing digitized video, this phenomenon shows up as a sporadic, bright-white dot in the reconstructed image. The sparkle spec guaranteed how few white dots appeared per frame of video.

The general problem seems to have only two practical

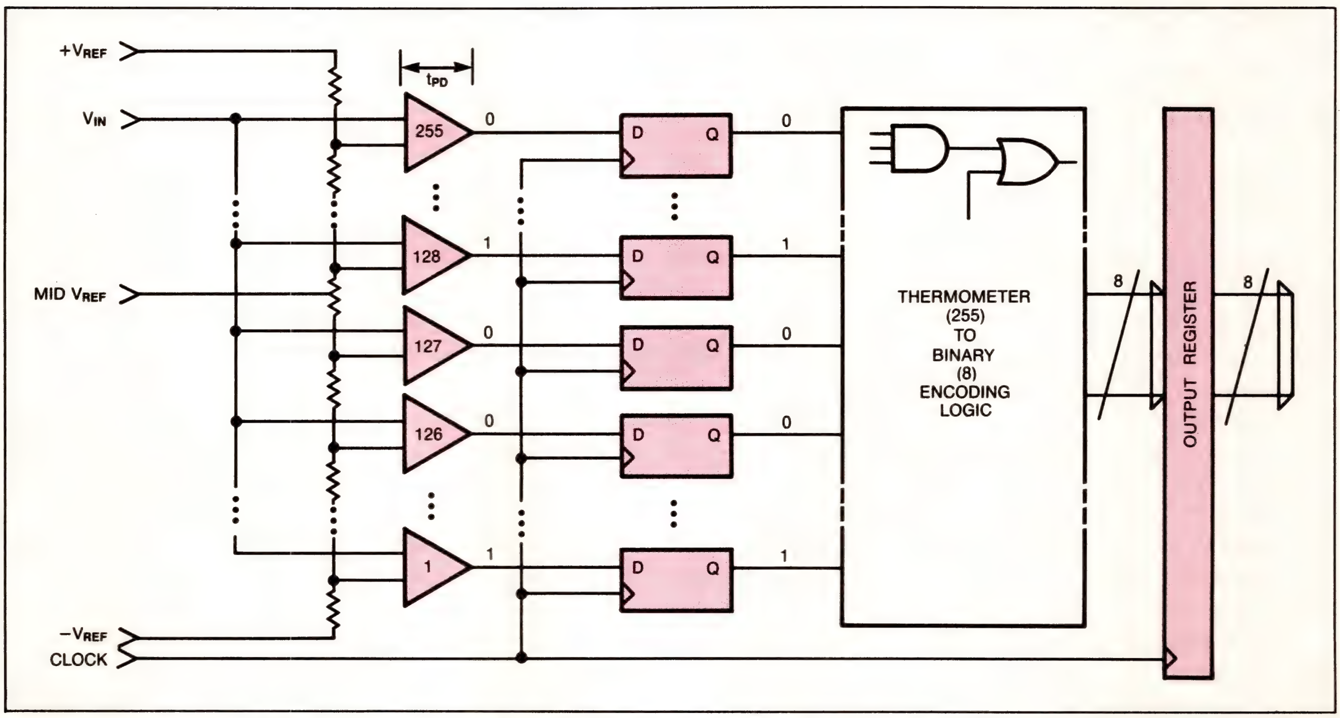


***Fig 1—"Bubbles" appear in thermometer-code lines** at high input slew rates, because of mismatches in the propagation delays of the individual comparators.*

solutions. The first is the use of a sample/hold circuit before the flash converter, with the transition from sample-to-hold timed such that the comparator outputs are stable when they are latched. This configuration is the analog equivalent of adding a synchronizer before latching an asynchronous input. A second solution counts on the degree of comparator-delay matching within the flash converter. If the matching is good enough to prevent double bubbles for input slew rates lower than some value, then you can simply limit the slew rate to the required value and no spurious codes will appear.

Don't let power bandwidth confuse you

The modern power-bandwidth specification is a measure of the described slew-rate phenomenon. Power bandwidth is a misleading term—it is not the −3-dB frequency of an amplifier—the actual quantity that should be limited is the input signal's slew rate, especially near the time when the comparator outputs are latched. The term power bandwidth comes from the normal method of testing for spurious codes. In this method, you apply a full-scale sine wave of known frequency to the converter, and then examine the resulting codes for *spuriousness.*

Spurious codes exist at frequencies above a certain value, and the power bandwidth is defined as the frequency just below that value. The sine wave is actually defining a maximum slew rate (2π times the peak amplitude times the frequency) in volts/sec. A low-frequency multiplexed system can violate this slew-rate limit if the multiplexer must switch between adjacent signals of low and high voltage. A power-bandwidth specification of less than one-half the sampling rate indicates that the system performance will degrade before the theoretical, Nyquist-limit input frequency is reached. **Fig 2** shows a classic example of this type of spurious code.

Practical testing for this type of spuriousness is easy, although the number of points required for a specific confidence level is often large. Designers commonly use FFT testing to infer the relative dynamic accuracy of a converter from its signal-to-(noise+distortion) ratio.

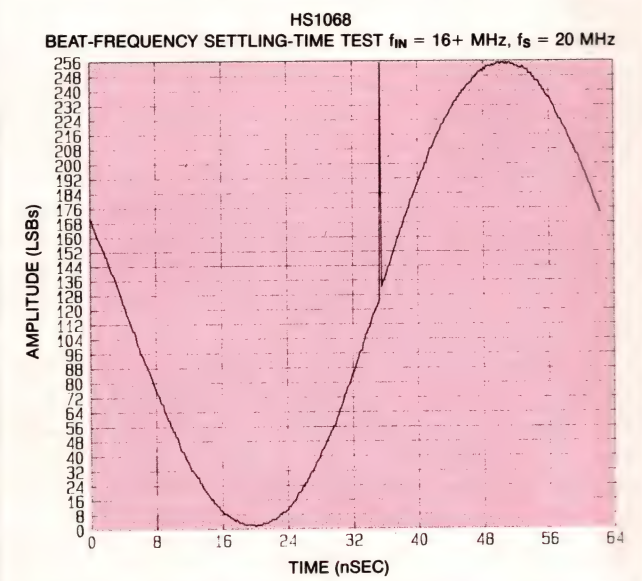


Fig 2—This classic example of a spurious-code spike is the result of exceeding the slew-rate capability of the converter.

TABLE 1—SIGNAL-TO-NOISE RATIO VS FREQUENCY

F_{IN} (MHZ)	10 FFT TESTS SNR (dB)	VARIANCE (dB)	EFFECTIVE BITS	CODE SIZE (LSBs) MINIMUM CODE	MAXIMUM CODE
TDC1048-BASED SUBSYSTEMS (HS1068)					
1.005	47.56	0.0097	7.60	0.65	1.41
2.005	46.35	0.0098	7.41	0.64	1.36
4.005	43.36	0.0228	6.91	0.49	1.46
8.005	40.57	0.0226	6.45	0.30	1.70
12.005*	37.41	0.0057	5.92	0.20	1.99
16.005	28.55	3.592	4.45	0.17	2.20
CA3318D-BASED SUBSYSTEM (BREADBOARD)					
1.005	37.47	0.0008	5.93	0.27	1.76
2.005*	38.34	0.0006	6.07	0.09	2.25
4.005	35.34	0.0025	5.58	1 MISSING	2.60
8.005	29.77	0.0072	4.65	1 MISSING	2.59
12.005	23.16	2.199	3.55	2 MISSING	3.42
MC10319-BASED SUBSYSTEM (SP1070)					
1.005	47.46	0.0059	7.59	0.59	1.54
2.005	46.33	0.0075	7.40	0.56	1.51
4.005*	42.67	0.0026	6.80	0.38	1.97
8.005	34.05	0.0062	5.36	0.01	3.40
12.005	29.04	0.0021	4.53	3 MISSING	4.66
16.005	25.62	0.0058	3.96	8 MISSING	7.54

*SHOWS THE POWER BANDWIDTH FREQUENCY

FFT testing is commonly used to infer the dynamic relative accuracy of a converter from its signal-to-(noise+distortion) ratio.

You can also express this ratio in units of ideal effective bits. A single spurious code will affect the spectrum by raising the wideband-noise floor, as in the case of the flat spectrum of an impulse. If you run a large number of signal-to-noise-ratio (SNR) tests, you can compute the variance in their readings. Some variance in SNRs is normal, because of the random phase of the sine wave's start and end points within the sampled-data buffer.

If the variance is larger than the random variance, you can assume that a spurious code exists. The magnitude of the variance (a large variance implies a large impulse error) provides an indication of its severity without requiring a spuriousness test for each code sampled. The tester used by the author's company uses 4k-point buffers and a Von Hann window to compute the SNRs. A Von Hann window is a $\cos^2$ function that forces the FFT to more closely approximate an ideal Fourier transform. The variance caused by random buffer-start points for 10 buffers is typically less than 0.1 dB. When the variance exceeds 0.1 dB, the tester declares a spurious code. Note that a large variance implies an error that occurs randomly. At extremely high slew rates, spurious codes may exist near almost every sine-wave zero crossing. The variance can be small in this situation, but the SNR measurements degrade rapidly and thus flag this type of error. **Table 1** shows the SNR, variance, and effective bits at different full-scale-input frequencies, all sampled at 20M samples/sec.

You can use a sampling-scope test, a variation of the beat-frequency test, to graphically plot the waveform—including any spurious codes—produced by the converter. At the author's company, this test is used to measure amplifier settling times, as it results in no quantitative information about spuriousness. A frequency synthesizer of good short-term stability serves to generate an input square wave. The converter is run at full speed, here 20 MHz, and a 4k-point buffer stores the information. Software is used to decimate the input file to produce a single beat-frequency cycle. Typical parameters used are: f_{IN}=2.004883 MHz, a decimation factor of 10, and f_S=20 MHz.

Decimation by 10 results in a single cycle of 409 points and an effective sample resolution of 1.22 nsec/point. At f_{IN}=4+ MHz, a resolution of 0.6 nsec/point is possible. **Fig 3** plots the results obtained from digitizing an input square wave that exhibits 1.2-nsec rise and fall times. Note that the input amplifier, which has typical rise and fall times of 18 to 20 nsec, is pushed into slew-rate limiting; thus the slew rate at the flash converter is significantly lower.

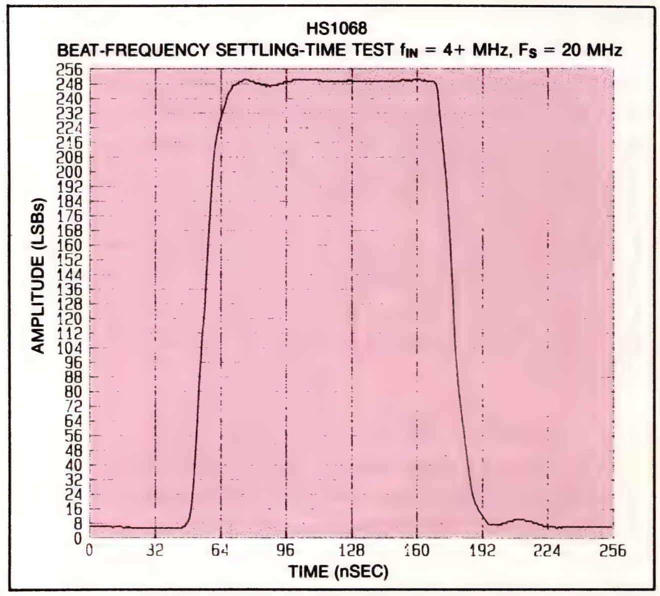


Fig 3—A settling-time plot uses a samplng-scope test. *This plot for the HS1068-based subsystem uses a variation of the beat-frequency test.*

Flash converters vary in performance

Other flash-converter architectures are in use, and their performance degrades in a different manner. For example, most CMOS flash converters use a switched-capacitor comparator architecture, which is necessary to autozero any temperature-dependent offset voltages at the comparators. A secondary effect of the presence of these capacitors at the comparators' inputs is large switching transients at the clock frequency, which reflect back into the driving amplifier. An extremely low output impedance at the driving amplifier will minimize the induced error, and extremely high bandwidth (much greater than the sampling frequency) is necessary to allow the amplifier to fully settle from the spike within one sample period.

At high slew rates, these capacitors seem to form a switched-capacitor filter that acts upon the input signal. The duty cycle of the clock governs the amount of time during which these capacitors are allowed to charge, and the frequency response of the system is modified at the converter by the clock's duty cycle. This frequency-dependent gain error will thus deviate from its normal response if the duty cycle of the clock changes with time or temperature.

The input amplifier acts as the current source that

charges these capacitors. The resulting capacitor voltage is equal to $I_{OUT} \times C$, multiplied by the time duration of the sampling portion of the clock period. The voltage transferred to each comparator is thus a function of the capacitor's value. Any variation in capacitance at each comparator will affect the width of each code, leading to aberrations in differential linearity.

How well this architecture works near Nyquist frequencies depends on the ability of the input amplifier to damp the switching spikes induced by the load (that is, the converter itself). **Fig 4** plots the output codes, shows them in histogram form, then takes their ratio to the ideal number of occurrences to generate the differential-linearity error. The tests in this example make no claim to fairness, as this converter is now specified at 15M samples/sec and has a power-bandwidth specification of only 5 MHz. Waveforms taken at 10+ MHz f_{IN} rarely show the classic spurious code, as experienced

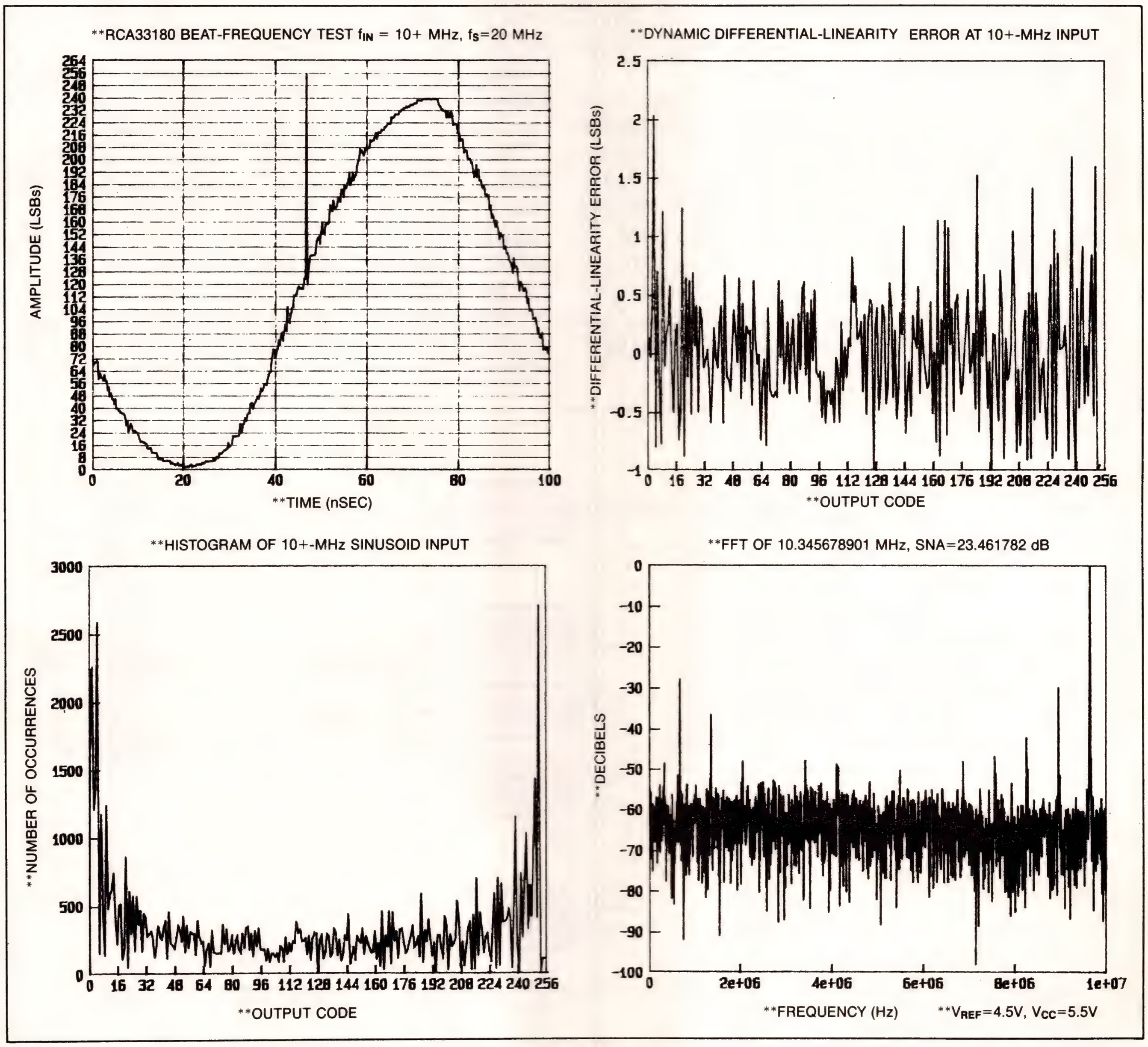


***Fig 4—Spurious codes and differential-linearity degradation** result when you drive a CMOS-processed flash A/D converter at frequencies beyond its capabilities.*

You can use a sampling-scope test to graphically plot the waveform that an A/D converter produces, including any spurious codes.

with the architecture discussed earlier. However, the histogram and dynamic-differential-linearity plot tell another story. The code widths vary erratically, and many codes do not exist at all.

A third flash architecture has the ability to limit the occurrence of spurious codes. This architecture merges a Gray-scale encoder into the comparator and latch-array sections, which then drive Gray-to-binary encoder logic. The practical advantage of using the Gray code stems from the minimal way the most likely errors affect the weight of the ultimate output code. **Fig 5** shows the architecture of Motorola's MC10319, a Gray-code-based flash converter.

Consider the differences in this configuration from that shown in **Fig 1.** Assume a difference in propagation delays between latching comparators 126, 127, and 128. Latching comparators 126 and 127 are 60 psec slower than 128. If comparator 128 is clocked before 126 and 127 catch up, 128 will show a One, while 126 and 127 are latched to Zero. If you think of these comparator outputs as thermometer codes (as in **Fig 1**), then this scenario would create a double bubble. Note that the initial encoding logic does not convert directly to binary, but to an intermediate Gray code.

Each comparator error will cause a corresponding error in one position of the Gray code. All Ones from the first to the 128th comparator would have resulted in a Gray-code representation described by the bit-pattern $C0_{16}$. The two comparator errors, however, will produce a Gray code described by $C3_{16}$, caused by erroneous inputs to the Gray LSB decoder and the Gray D_2 decoder. The resulting binary output code will be 82_{16}, or 130_{10}. This output code would be in error by 130−128, or 2 LSBs. Contrast this result with architectures one and two, which produce an output code of 255, for an error of 127 LSBs. All three converters are wrong. The difference is in the magnitude of the error. **Fig 6** plots the performance of a flash-converter subsystem using the Gray-code architecture of **Fig 5**.

The output codes that exhibit errors will still begin to show up when input signals exceed the circuit's slew-rate limit, which is determined by the differential propagation times. However, testing to detect these occasional small-magnitude errors is not as easy as it is for the first architecture. The Gray scaler minimizes the magnitude of the error even when the power bandwidth specification is greatly exceeded. The SNR variance is not large across several buffers, although

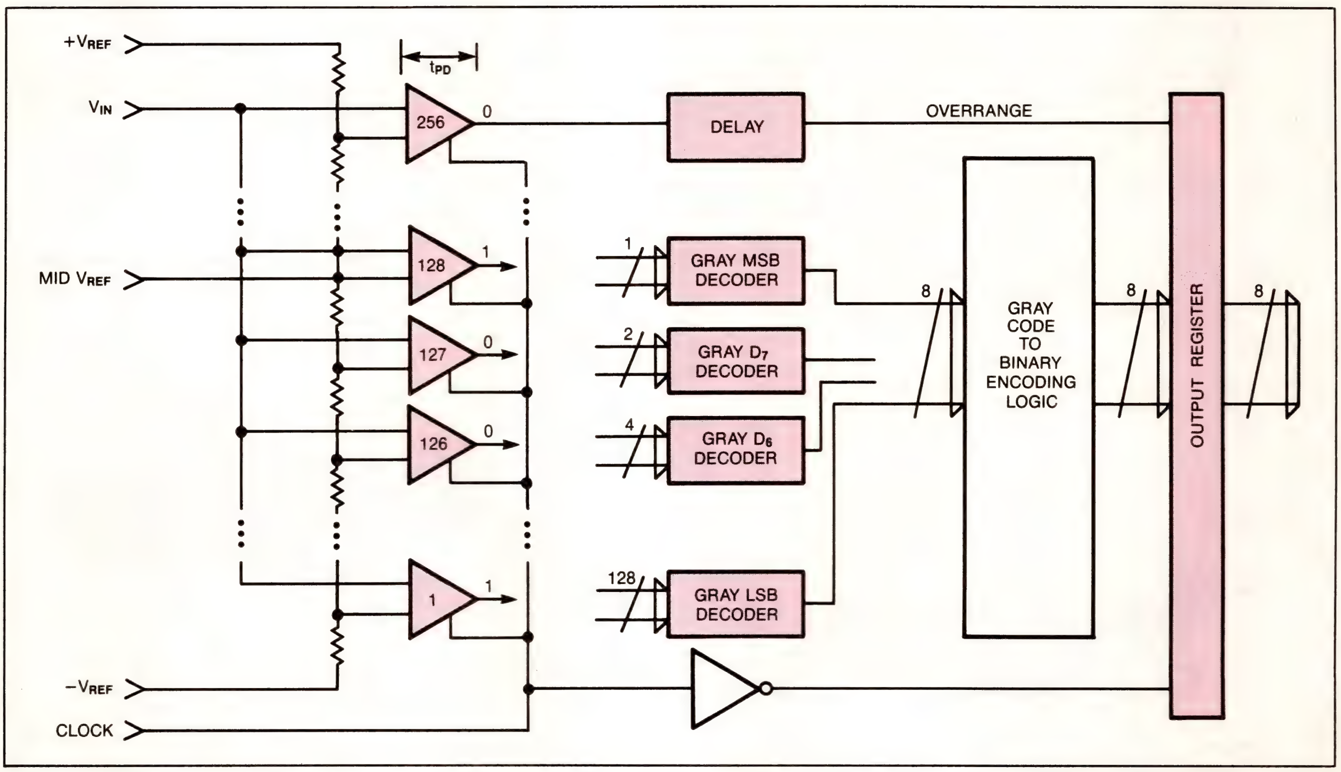


Fig 5—Equivalent "bubbles" at high slew rates *cause only minimal output-code errors in a Gray-code-based flash converter.*

the SNR will degrade significantly because of the equivalent wideband noise (see **Table 1**). Differentiating the amount of degradation caused by slew-rate-induced errors from that caused by converter noise, crosstalk, and integral nonlinearity in the amplifier is not a straightforward problem. The problem, then, is how to specify an equivalent no-spurious-codes power bandwidth for converters that use different architectures.

One solution is evident from the examination of the histograms of output codes for full-scale sine waves of increasing frequency. Although Gray-scale flash converters do not exhibit spurious codes as easily identifiable random events, the evidence of slew-rate-related problems is clear in the code widths portrayed in the histograms. When these histograms are normalized to show dynamic differential-linearity error, this dynamic error can be directly compared to differential-linearity

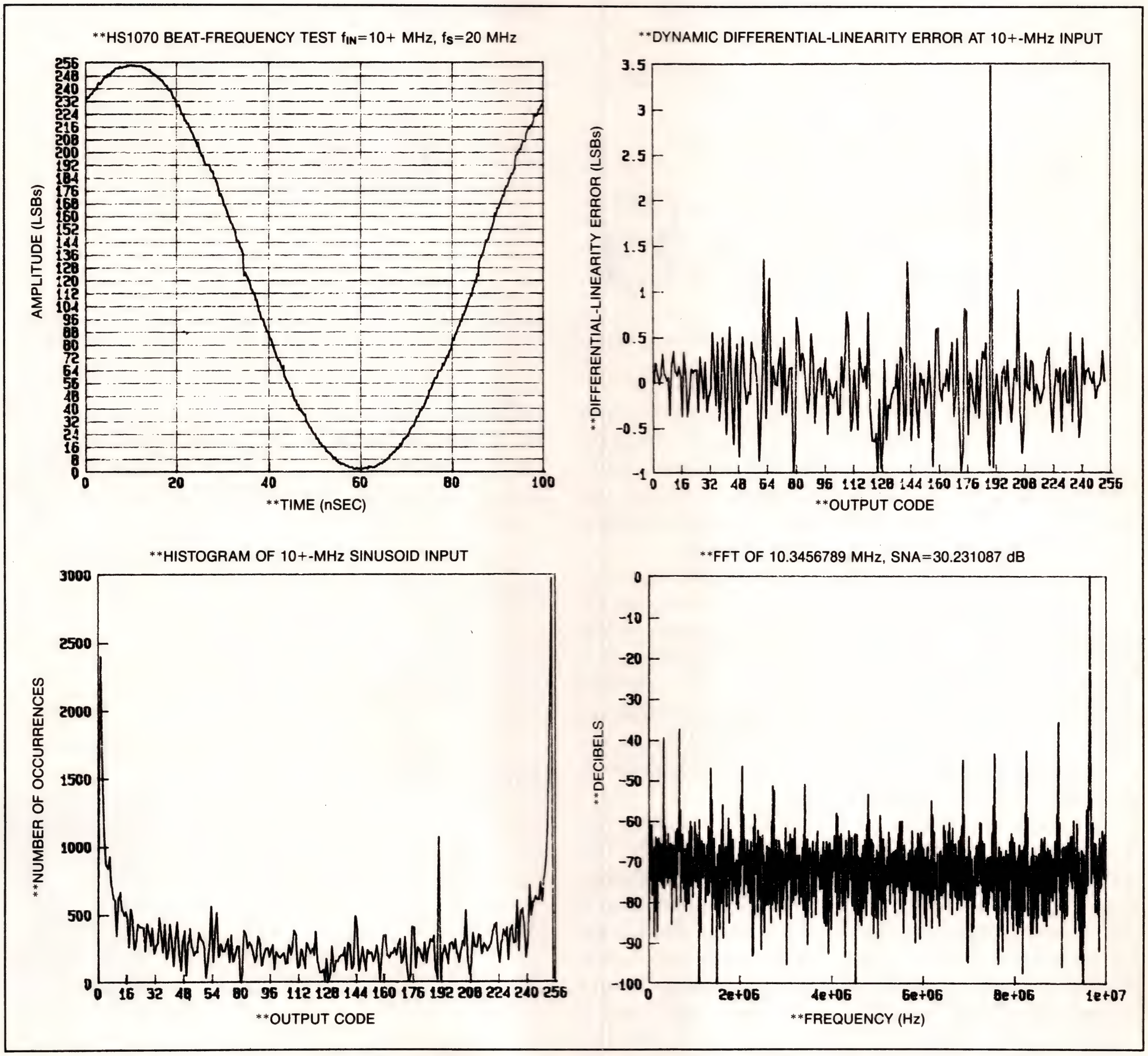


*Fig 6—**These plots from a Gray-scaled flash converter** show no classical spurious codes. Slew-rate-induced problems appear as missing or widened codes.*

Most CMOS converters use switched-capacitor comparators, which can reflect switching transients at the clock frequency into the driving amplifier.

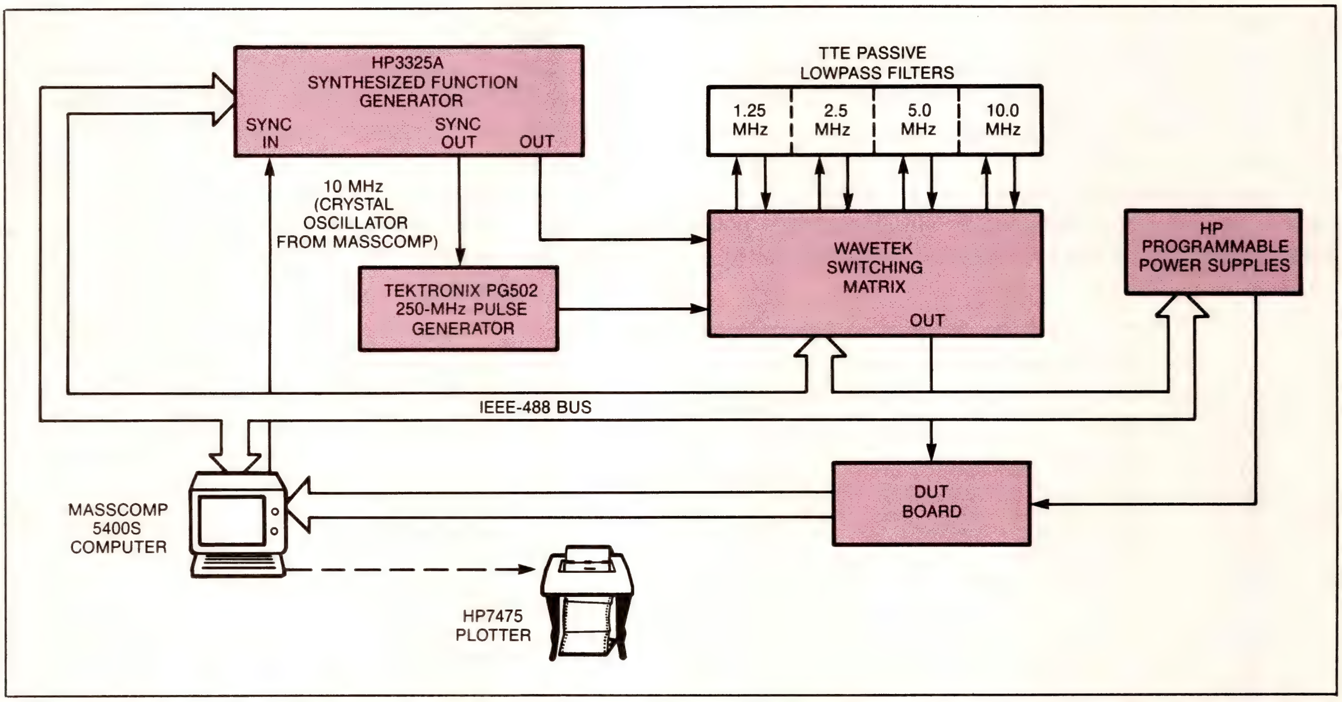


Fig 7—Reflecting the testing principles outlined in the text, *this test system used at Hybrid Systems measures spuriousness and differential nonlinearity at high frequencies.*

error measured at dc. You can define equivalent power bandwidth as the full-scale input frequency that produces differential-linearity errors greater than 1 LSB. This frequency is of interest because it defines the possibility of missing codes, although always-missing codes appear at slightly higher frequencies.

Using this definition of power bandwidth, the only converter measured here that is capable of full-power, Nyquist-frequency operation (at 20M samples/sec) is TRW's TDC1048 bipolar converter of architecture one. This mode of operation is guaranteed only to a specified confidence level, and slew rates above this limit are tolerated only if the converter is preceded by an extremely fast sample/hold circuit that's timed to settle at the converter's aperture (sampling) point.

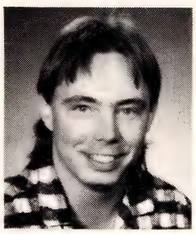
The author's company uses these tests to qualify the HS1068 self-contained flash-conversion system. The parts that are capable of full-power, Nyquist-frequency operation over temperature are graded out and offered for sale at a premium. Applications where the analog signal contains only limited high-frequency signal power, such as the digitization of broadcast-quality video, can benefit from the lower power consumption and dc stability offered in the SP1070, which is based on Motorola's MC10319 flash converter.

The test system itself **(Fig 7)** consists of a MassComp workstation that controls Hewlett-Packard and Wavetek instruments over a GPIB bus. The software, written by Seth Hollub, is available for licensing; it runs under the Unix operating system from a menu, or at the C-shell level. **EDN**

Acknowledgment

The author would like to thank Ted Hanna of Motorola Semiconductor for his help in explaining the intricacies of the MC10319 Gray-coded flash converter.

Author's biography



Eric Blom is a principal engineer with the Hybrid Systems Div of Sipex Corp. He has been with the company for two years; his present responsibilities are in new-product design. Eric has a BSEE from Worcester Polytechnic Institute. His hobbies include windsurfing, sailboat racing, ice hockey, and jug band music.

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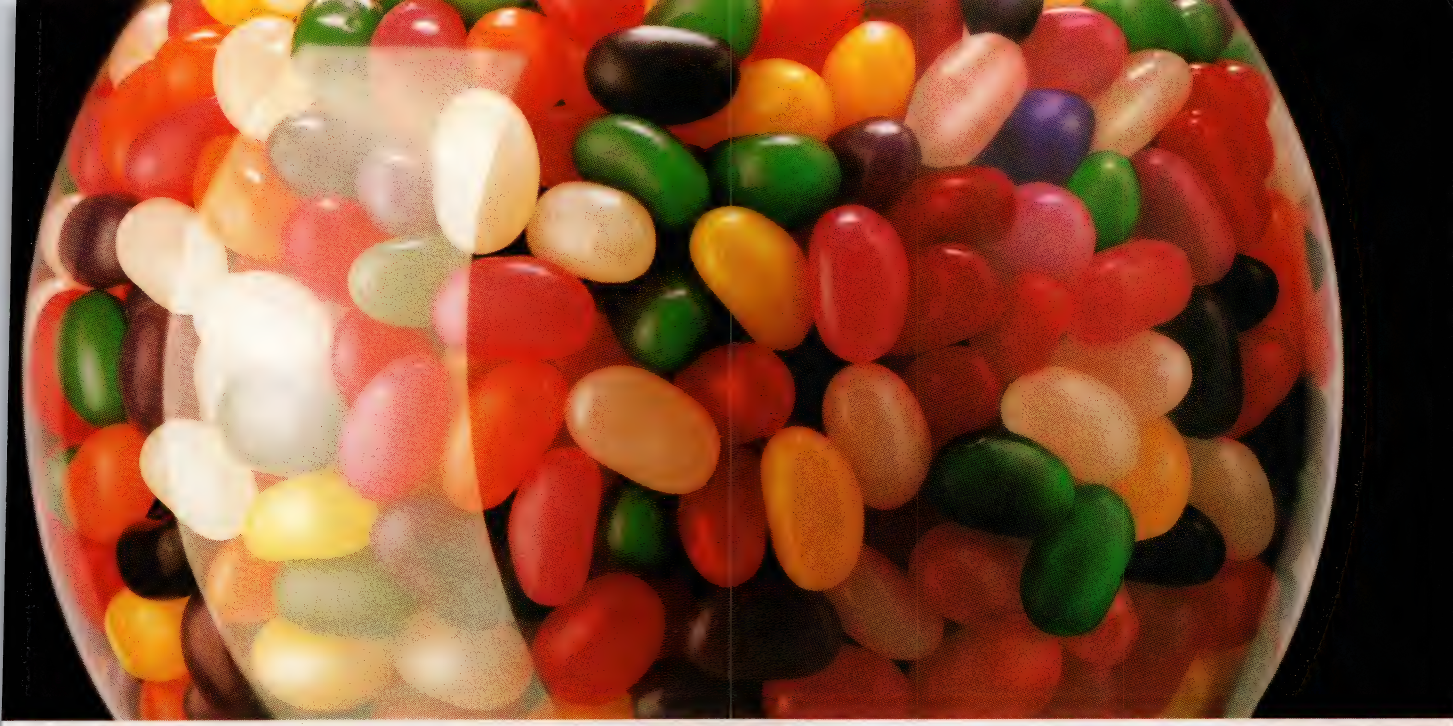

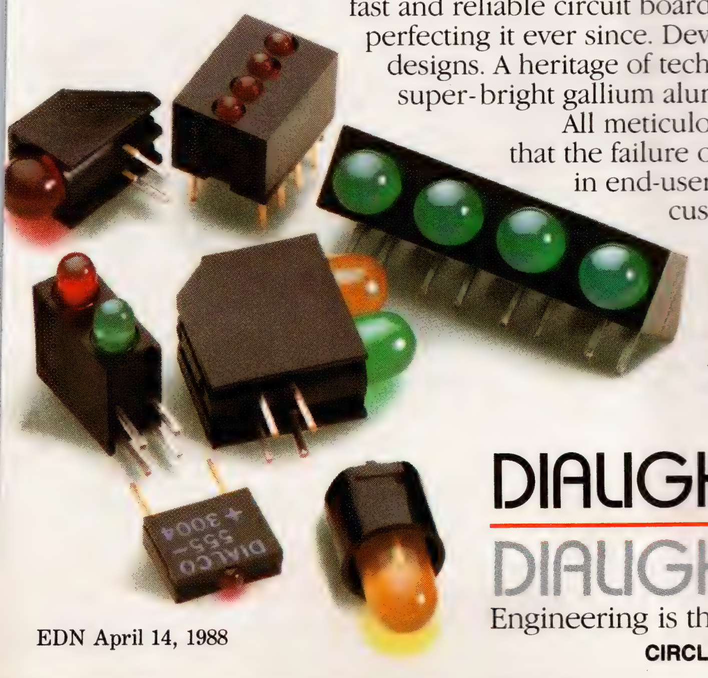

Signal-powered switch connects devices

James Dean
National Research Council,
Ottawa, Ontario, Canada

Fig 1's switch can selectively connect a terminal, personal computer, or any other originating device (DTE) to one of four receivers such as modems and printers. Using a thumbwheel switch, you select which device you want to connect. The circuit handles data rates to 19.2k baud without any signal degradation or crosstalk.

Four Maxim DG509A dual 4-channel multiplexers switch the eight critical RS-232C lines. The Maxim multiplexers suit this application because they consume only 20 μA typ, handle ±18V signals, exhibit only 130Ω on-resistance typ, and have input protection.

The unit doesn't require an external power supply because it gets its power from the RS-232C ready lines (DTE pins 4 and 20, DCE pins 5, 6, and 8); the SI7661 converter provides the negative supply. The Schottky power diodes in the dual-diode MBR2045CT packages ensure that the switch draws its power from whichever connected device has the highest output voltage at its RS-232C connector. The low forward-voltage drop of these diodes guarantees that the internal-protection diodes of the switch ICs do not conduct. The circuit's V⁺ supply is merely one Schottky-diode drop below the highest signal potential. **EDN**

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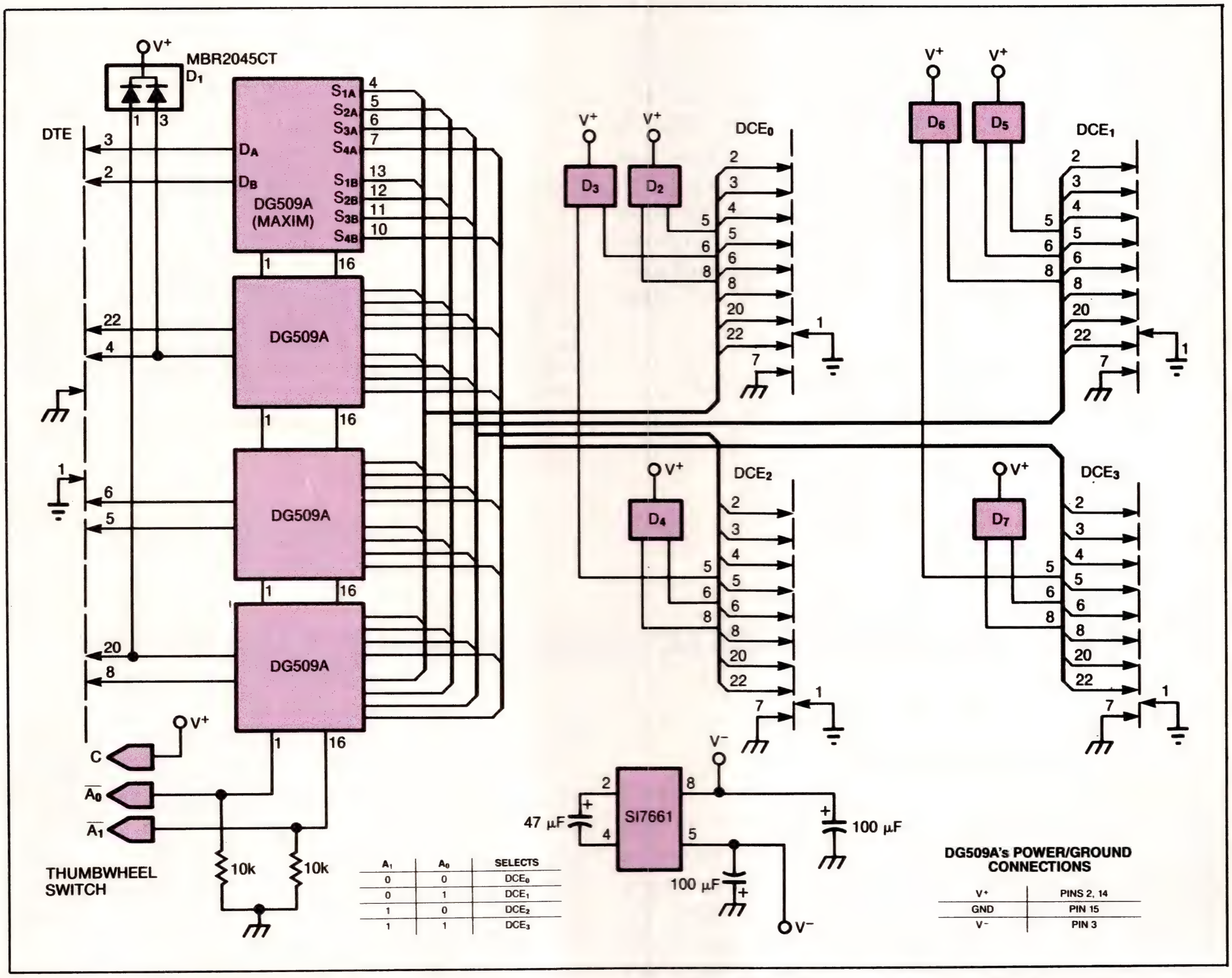

A1	A0	SELECTS
0	0	DCE0
0	1	DCE1
1	0	DCE2
1	1	DCE3

V+	PINS 2, 14
GND	PIN 15
V−	PIN 3

Fig 1—This signal-powered selector uses analog switches *to connect one of four RS-232C devices to a terminal or personal computer.*

XOR gate doubles counting frequency

Andrew Gorajek
Adelaide Microelectronics Centre, Technology Park, The Levels, South Australia

Suitable for noisy industrial environments and requiring no passive components, the frequency doubler in **Fig 1** inserts an XOR gate into the first stage of a digital counter. The circuit works with virtually any counter and XOR gate. An XOR gate, in series with the counter's clock input, works as a digitally controlled inverter. The gate gets its control signal from the counter's first-stage output, Q_0.

After resetting, output Q_0 is low and the MC14070B XOR gate, IC_1, acts as a noninverting buffer. Because the MC14518 counter, IC_2, counts on the rising edges of the clock signals, the first positive-going transition of the input signal makes IC_2's Q_0 output go high **(Fig 1b)**, which makes IC_1 an inverter. The next negative-going transition of the input signal appears to the counter's clock input as a positive-going transition and change's Q_0 to low. Further transitions of the input signal will cause this sequence to repeat. The resulting clock signal has twice the frequency of the input and consists of short pulses whose width is the sum of the propagation delays introduced by the counter and the XOR gate (t_{P1} and t_{P2}). **EDN**

To Vote For This Design, Circle No 748

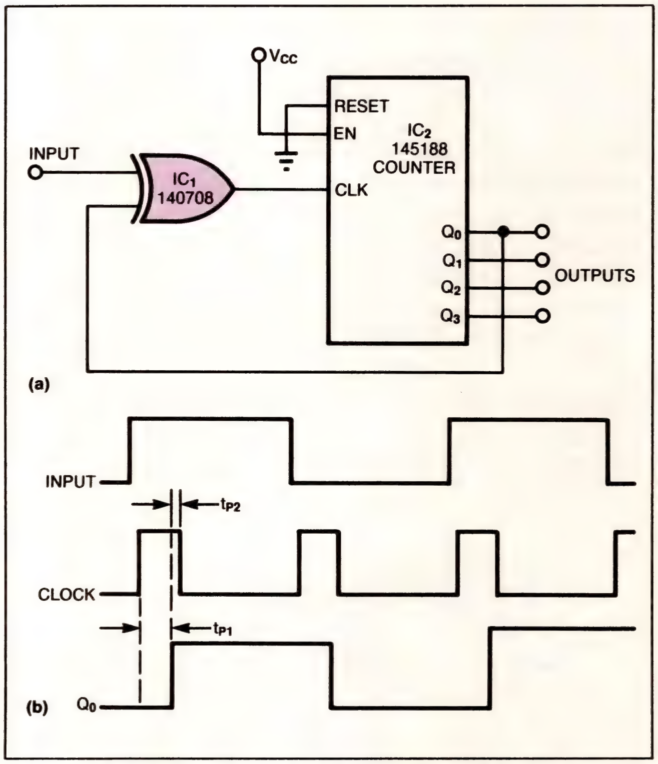

*Fig 1—**An XOR gate in series with a counter's clock input** effectively doubles the input-clock rate. The XOR gate transforms the input signal into a series of short pulses whose width is the sum of the gate's and the counter's propagation delays. Feeding back the counter's Q_0 output to the XOR gate makes the gate a controlled inverter. Inverting the negative-going input transitions allows the counter to count both positive- and negative-going edges.*

Time-slotting scheme speeds loop execution

Barry Kaufman
Multipath Inc, Pine Brook, NJ

Real-time, embedded systems that must run at high speed often cannot afford the overhead of managing multiple, asynchronous interrupts, and in these cases a control loop is necessary. The µP must traverse the control loop fast enough to service all interrupts within a specified time interval, however. If your control-loop program is too long, you can employ a simple time-slotting scheme to speed execution of the control loop.

First, separate your time-critical code from your nontime-critical code. The time-critical code then becomes the main body of your control loop. Next, determine how much time you have left in your control-loop interval after executing the time-critical code. Then divide your nontime-critical code into segments, each of which can execute within the remaining portion of the control-loop interval.

In **Listing 1**, a selector mechanism inserted at the

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LOW PASS Model	*LP-	10.7	21.4	30	50	70	100	150	200	300	450	550	600	750	850	1000
Min. Pass Band (MHz) DC to		10.7	22	32	48	60	98	140	190	270	400	520	580	700	780	900
Max, 20dB Stop Frequency (MHz)		19	32	47	70	90	147	210	290	410	580	750	840	1000	1100	1340

Prices (ea.): P $9.95 (6-49), B $24.95 (1-49), N $27.95 (1-49), S $26.95 (1-49)

HIGH PASS Model	*HP-	50	100	150	200	250	300	400	500	600	700	800	900	1000
Pass Band (MHz)	start, max.	41	90	133	185	225	290	395	500	600	700	780	910	1000
	end, min.	200	400	600	800	1200	1200	1600	1600	1600	1800	2000	2100	2200
Min. 20dB Stop Frequency (MHz)		26	55	95	116	150	190	290	365	460	520	570	660	720

Prices (ea.): P $12.95 (6-49), B $27.95 (1-49), N $30.95 (1-49), S $29.95 (1-49)

*Prefix P for pins, B for BNC, N for Type N, S for SMA *example:* **PLP-10.7**

C105 REV.D

CIRCLE NO 104

end of the time-critical code successively runs one segment of nontime-critical code during each pass through the control loop. The code initializes a time-slot index prior to entering the endless control loop. The index-control routine located at the bottom of the loop increments the index (or resets it to 1 after reaching the maximum count). Each nontime-critical routine runs only if its time-slot identification number equals the index. Although this example uses a RAM location for the index, you can employ an unused μP register.

Alternatively, you can use an even simpler scheme in which the main control loop jumps directly to the start of a particular nontime-critical segment based on an address found in a variable. Each segment, as it runs, then overwrites this variable's contents with the starting address of the next segment in the round-robin chain of nontime-critical segments. This scheme eliminates the overhead of maintaining the index and bypassing unselected nontime-critical routines.

To Vote For This Design, Circle No 746

LISTING 1—TIME-SLOTTING SCHEME FOR Z80 PROGRAM

```
; EXAMPLE OF TIME SLOTTING TO INCREASE SPEED
;
;     ***** INITIALIZATION *****
;
INDEX:     EQU  ADDR        ; addr = RAM address of the index.
;
           LD A,1           ; load accumulator with 1.
           LD (INDEX),A     ; put it in RAM address "INDEX".
;
;
START:                      ; Top of the endless loop.
;
;     ***** TIME CRITICAL CODE *****
;
                            ; This section of the loop is
                            ; for your time critical code.
                            ; The code is not time slotted.
                            ; It will run on every pass
                            ; through the loop.
;
;     ***** NON TIME CRITICAL CODE *****
;
TSLOT1:    LD A,(INDEX)     ; Load RAM index into accumulator.
           CP 1             ; compare with time slot id. #1
           JP NZ,TSLOT2     ; (could be 1 - 4 for this example).
                            ; jump to next routine if this is
                            ; not slot #1.
;
                            ; This section of the loop is for
                            ; your non time critical code
                            ; that runs in time slot #1.
;
TSLOT2:                     ; Same as above but for next time slot.
;
;     ***** INDEX CONTROL CODE NEAR BOTTOM OF LOOP *****
;
           LD HL,INDEX      ; HL points to index address in RAM.
           LD A,4           ; Load acc. with highest time slot #.
           CP (HL)          ; Is index at highest #?
           JP Z,RESIND      ; Jump if yes.
           INC (HL)         ; Otherwise increment the index
           JP FINISH        ; and go to bottom of the loop.
RESIND:    LD A,1           ; load accumulator with 1.
           LD (HL),A        ; and reset the index in RAM.
;
FINISH:    JP START         ; Loop again but with new index #.
```

Algorithm determines highest priority task

S Murugesan
ISRO Satellite Centre, Bangalore, India

The fastest real-time systems often use hardware priority encoders, but you can replace such special-purpose hardware with a software routine based on the successive-refinement algorithm in **Fig 1**'s flowchart. The algorithm works with an 8-bit word; each of the word's asserted bits represents a prioritized task, T_P, needing attention. The most significant bit corresponds to the highest priority task, the least significant bit to the lowest. The algorithm zeros in on the highest priority asserted bit regardless of how many lower-priority bits are asserted.

This algorithm is much faster than the usual shift-and-test method of finding the highest priority asserted bit. Instead, it performs a series of tests and branches based on the value of the 8-bit word. Either high-level languages or assembly-level code can handle the simple comparisons and branches, and you can easily extend the algorithm to handle more than eight tasks. Simply use as many 8-bit words as necessary to accommodate the number of tasks you must prioritize. Before using the algorithm, test the bytes in descending order of priority to determine which is the most significant nonzero byte, and then submit that byte to the algorithm. **EDN**

To Vote For This Design, Circle No 749

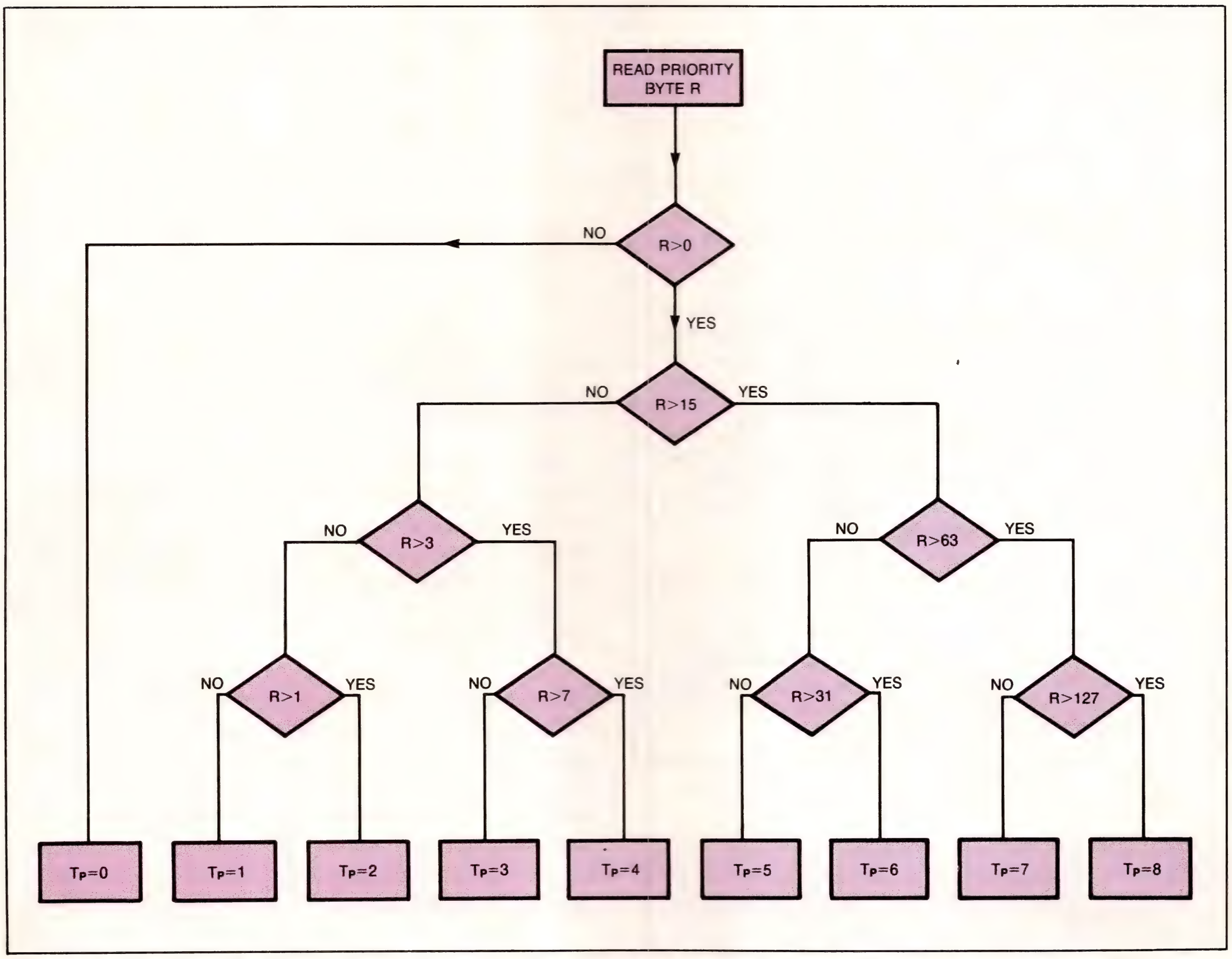

***Fig 1—This easily encoded, successive-refinement algorithm** homes in on the most significant asserted bit in an 8-bit word. Each asserted bit represents a prioritized task (T_P) requesting attention. This algorithm is faster than conventional shift-and-test methods.*

ISSUE WINNER

The winning Design Idea for the January 21, 1988, issue is entitled "Low-current voltage tripler is inexpensive," submitted by Henry Yio of Endevco (San Juan, CA)

XOR gates generate complementary signals

Kálmán L J Molnár
Consultant, München, West Germany

Some applications, such as driving 3-state buffers for data multiplexers or for biphase clocks in high-speed systems, require complementary signals having a small time skew and nearly simultaneous transitions. An earlier Design Idea ("Transmission gate improves clock driver," EDN, November 12, 1987, pg 287) uses a transmission gate to equalize the path delays. Although this scheme results in an output skew of less than one-half of a gate delay, it works only for CMOS designs.

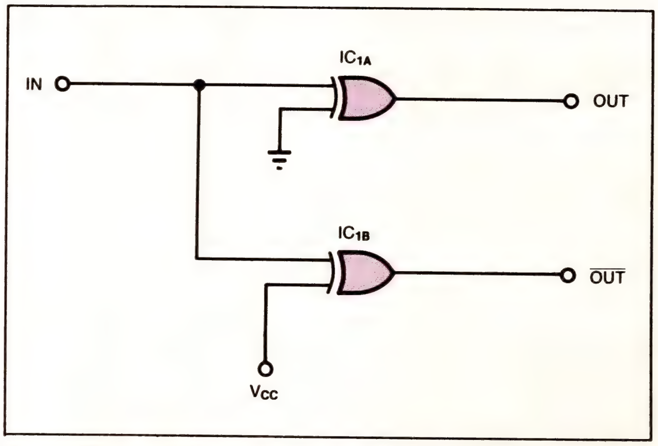

***Fig 1—This simple complementary-driver circuit** uses XOR gates for both the inverting and noninverting paths, and therefore the output skew is equal to the chips' manufacturing tolerance.*

Fig 1 shows a more accurate and general solution for both TTL and CMOS designs. Here, XOR gates function as both inverting and noninverting gates. Because the circuit has the same number of gates in each path, the output skew is merely that of the manufacturing tolerances of the gates' propagation delays—often well below 0.5 nsec.

For CMOS systems, practically any type of XOR gate will work. However, the advanced-CMOS logic (ACL) families have the greatest drive capability, the shortest gate delays, and the tightest manufacturing tolerances. For TTL systems, compatible CMOS types such as the ACT or S/AS86 families are preferable. Do not use low-power TTL versions (LS or ALS), because they have large propagation-delay differences when one XOR gate is inverting and the other is noninverting.

EDN

To Vote For This Design, Circle No 747

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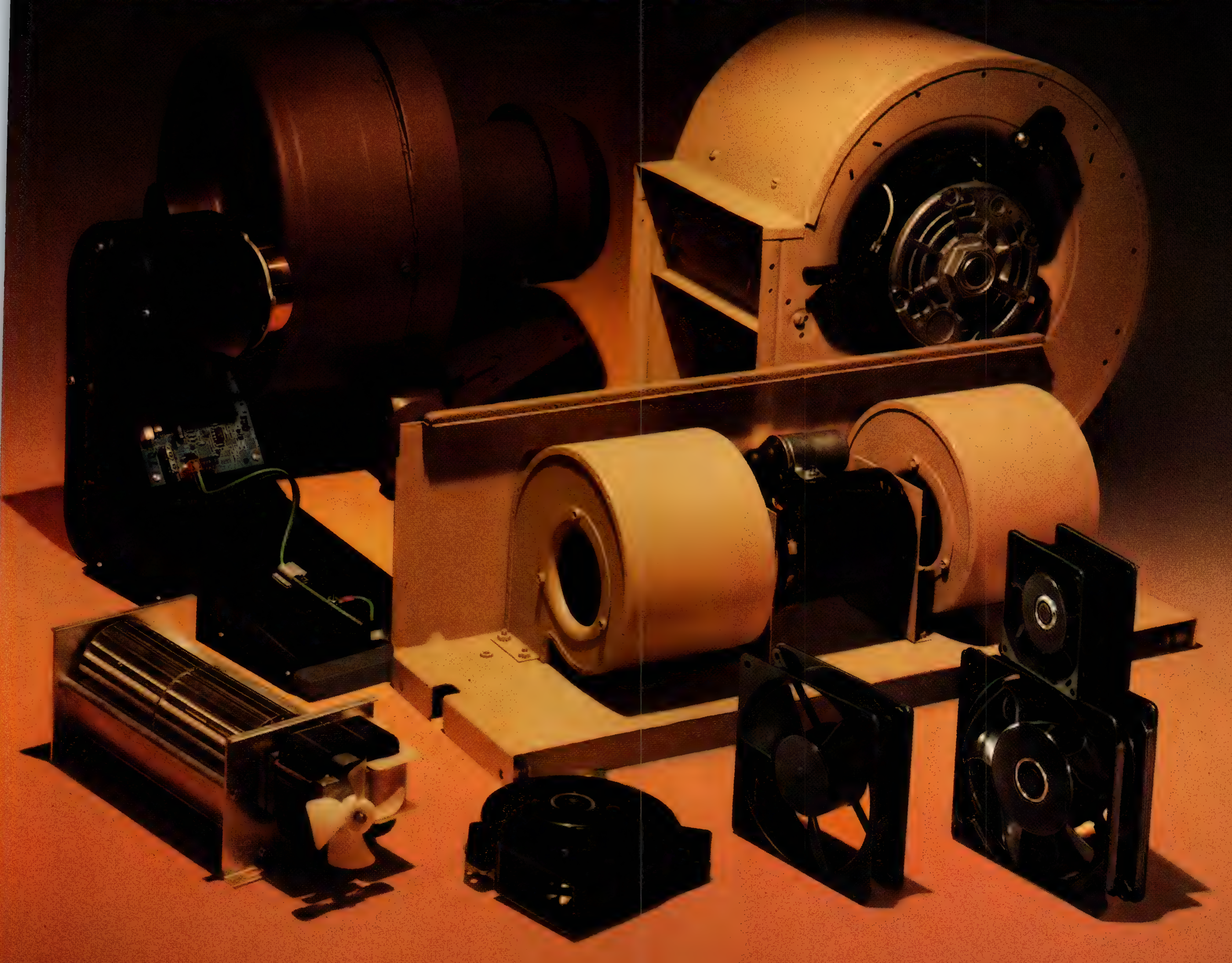

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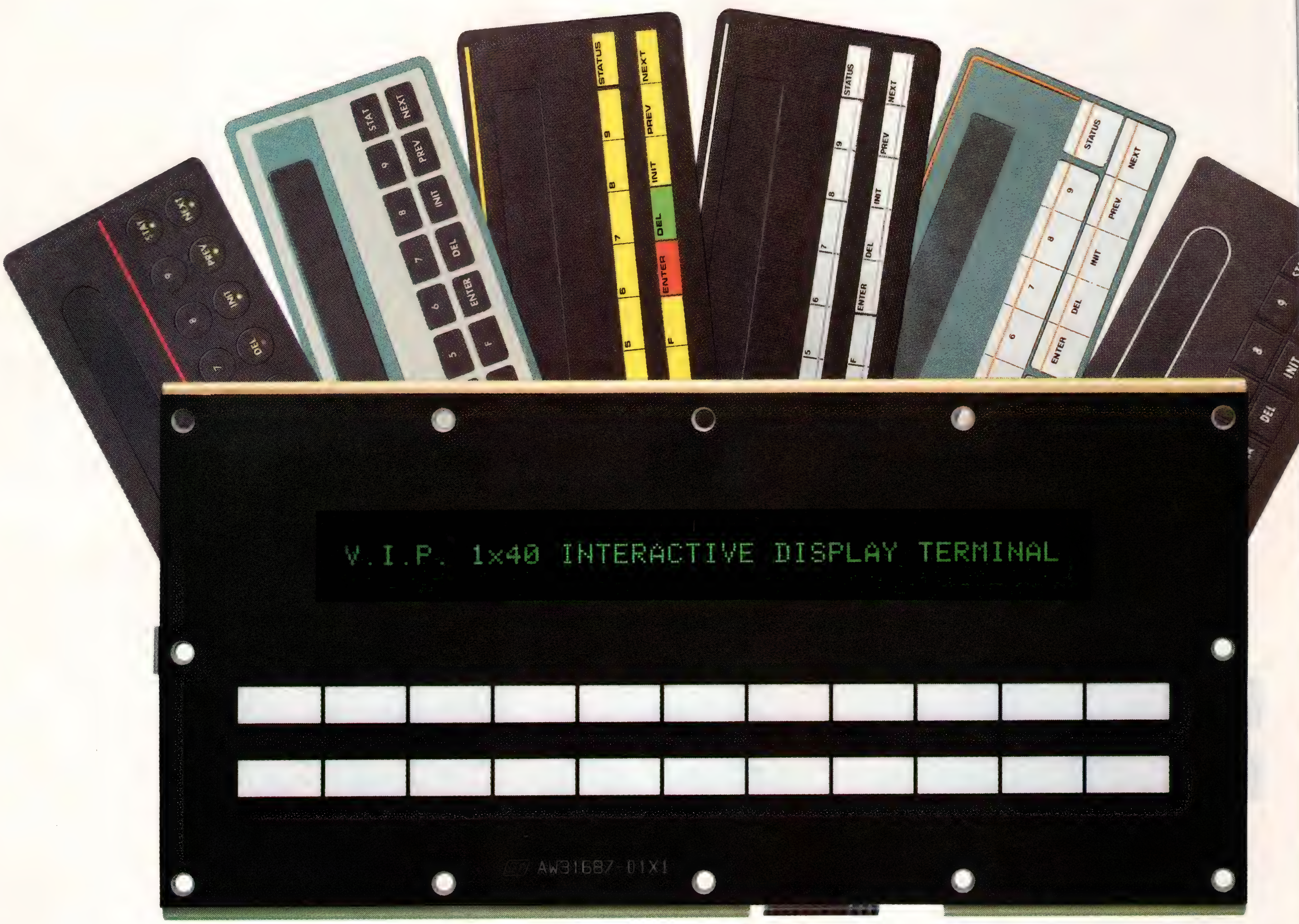

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Circle No. 107 for immediate application

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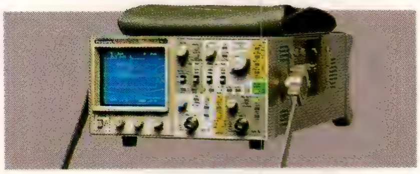

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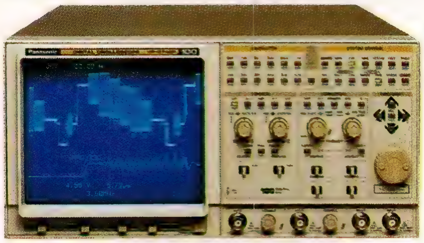

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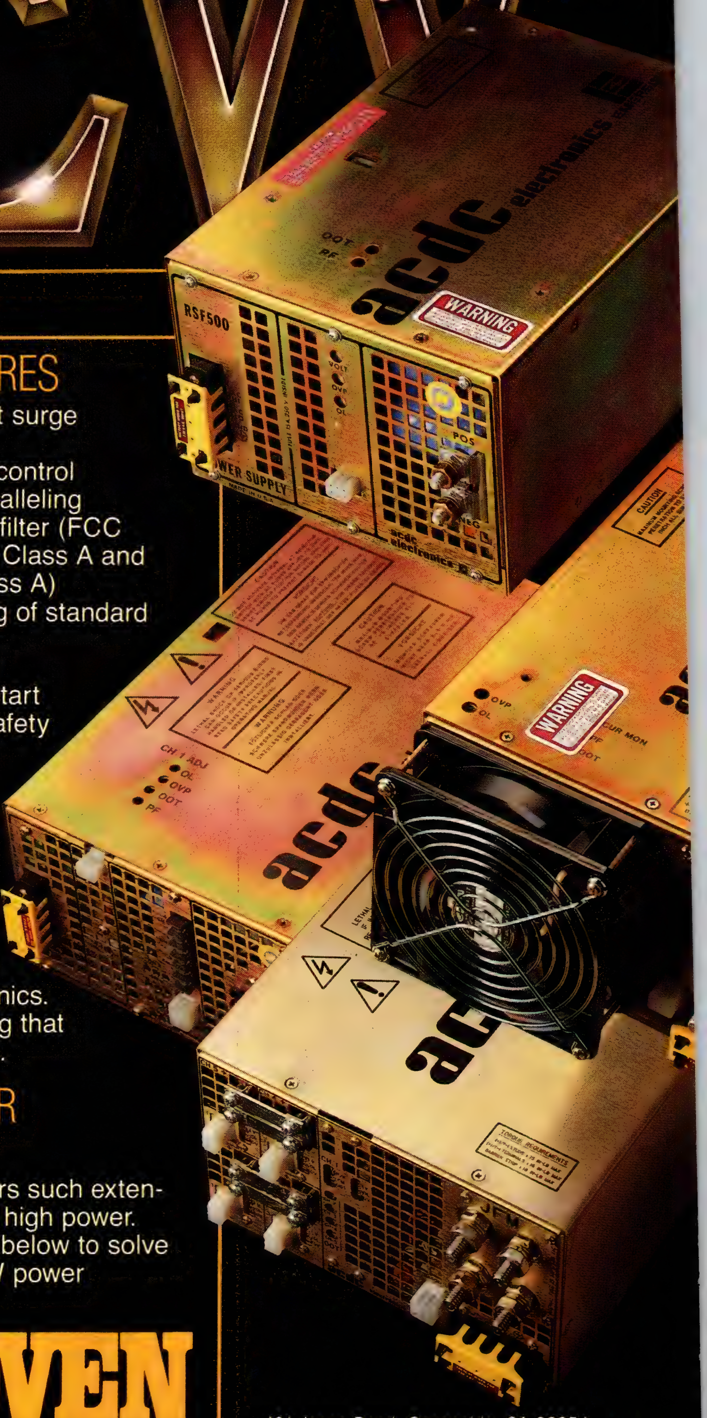

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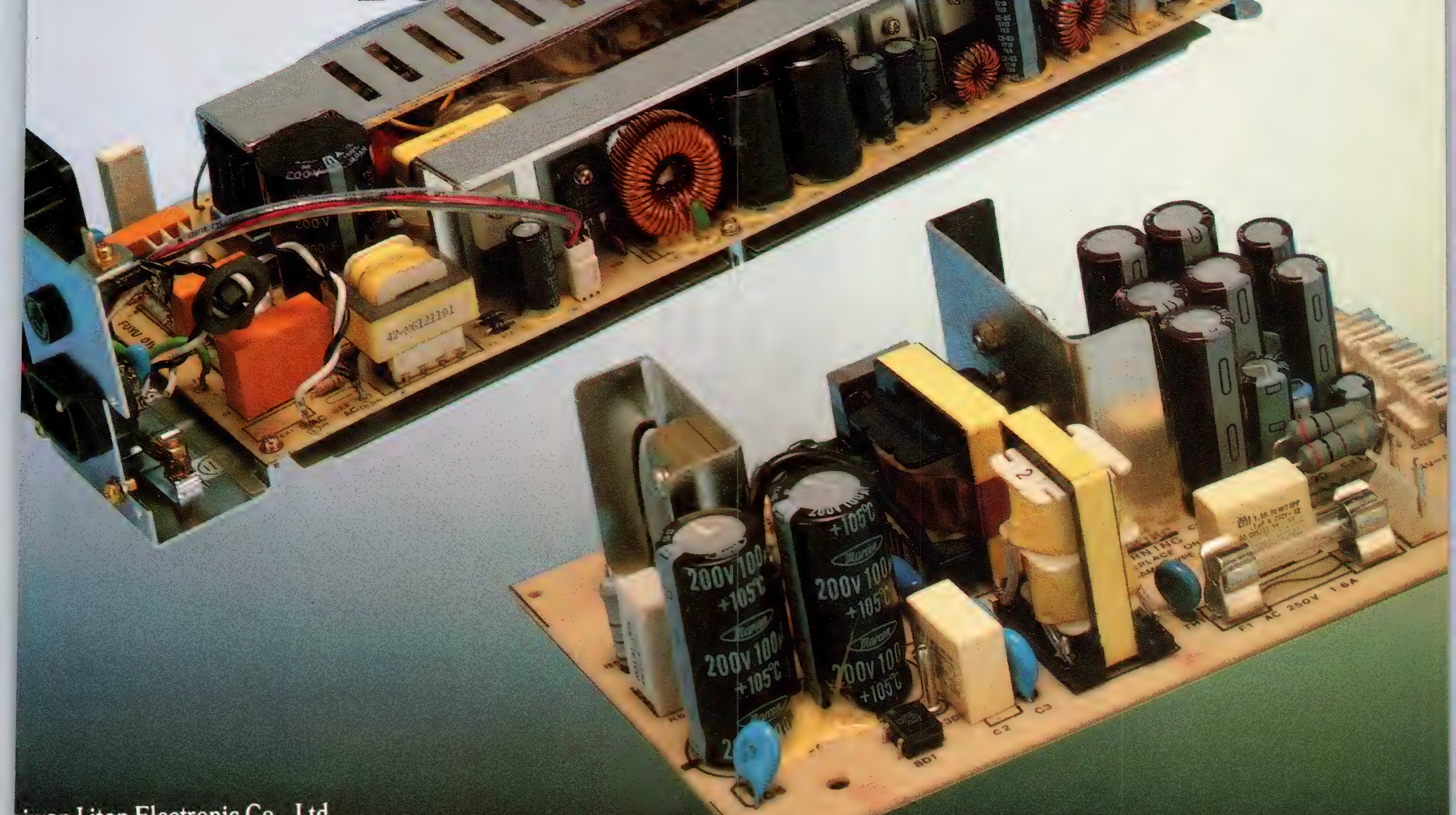

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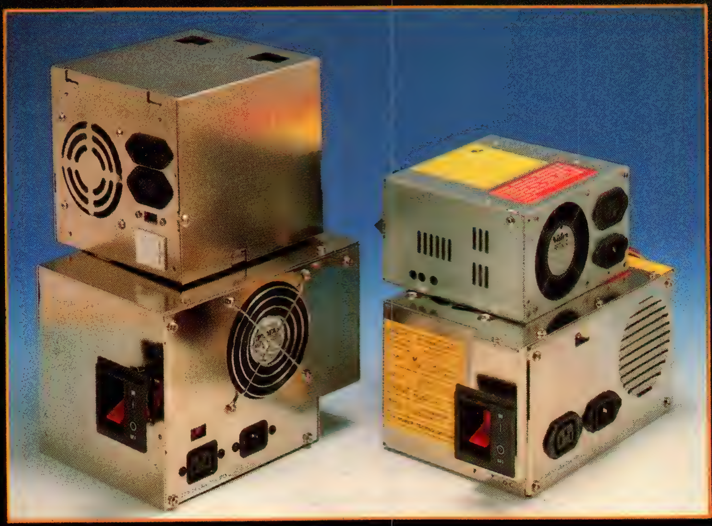

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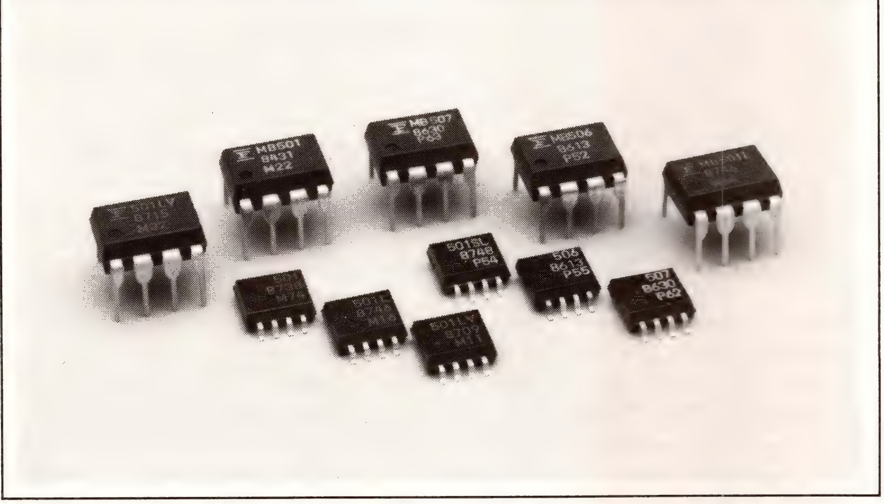


ECL PRESCALERS

- *Include low-power versions*
- *Accept input frequencies to 1 GHz*

The MB501 family encompasses four types of ECL prescalers. The standard version consumes 30 mA at 5V. The 501L and 501SL consume 10 and 5 mA, respectively. The 501LV is a low-voltage device that operates from a 3V suppply and consumes 12 mA. The prescalers divide the input frequency by a modulus of 64 or 128. A pulse-swallow feature allows the prescalers to implement a modulus of 65 or 129. All members of the MB501 family have output levels of 1.6V p-p, except for the MB501LV version, which produces 1.1V p-p. The devices come in flatpacks or in 8-pin DIPs. $3 to $7 (1000).

Fujitsu Microelectronics Inc, 3320 Scott Blvd, Santa Clara, CA 95054. Phone (408) 562-1000.

Circle No 351

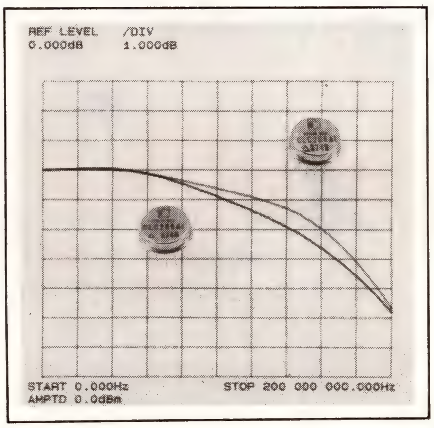
24-PIN PAL ICs

- *Feature high-speed operation*
- *Come in combinatorial and registered output types*

PAL20R8-12 programmable array logic (PAL) ICs provide 12-nsec propagation delays, making them some 20% faster than competing 24-pin PAL devices, including the vendor's own line of 15-nsec devices. The ICs come in a variety of types with combinatorial and registered outputs. The PAL20L8-12 has eight combinatorial outputs; the PAL20R8-12 has eight registered outputs; the PAL20R6-12 has two combinatorial and six registered outputs; and the PAL20R4-12 has four combinatorial and four registered outputs. You can obtain the devices in plastic or ceramic 24-pin SkinnyDIPs, and in 28-pin PLCCs. PAL20R8-12, in a DIP, $15.85 (100).

Advanced Micro Devices, 901 Thompson Pl, Box 3453, Sunnyvale, CA 94088. Phone (408) 732-2400.

Circle No 353



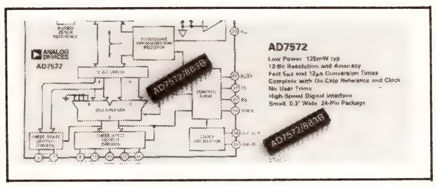
OP AMPs

- *Provide bandwidths to 180 MHz*
- *Feature slew rates of 2400 and 3400V/μsec*

The CLC205 and CLC206 wideband op amps use current feedback to achieve their high speed. The CLC205 provides a small-signal (−3 dB) bandwidth of 170 MHz, a rise time of 2.2 nsec, a settling time (to 0.1%) of 22 nsec, and a slew rate of 2400V/μsec. The device can supply 50 mA of output current. The CLC206 has a small-signal bandwidth of 180 MHz, a rise time of 2 nsec, a settling time of 19 nsec, and a slew rate of 3400V/μsec. The IC can supply 100 mA of output current. Both devices come in versions for the industrial and military temperature ranges. Military-grade versions, $56; industrial-grade versions, $138 (100).

Comlinear Corp, 4800 Wheaton Dr, Fort Collins, CO 80525. Phone (303) 226-0500.

Circle No 352



HIGH-SPEED ADC

- *Provides 12-bit resolution*
- *Features 5-μsec conversion time*

The AD7572 12-bit A/D converter is processed to MIL-STD-883B rev C and offers a 5-μsec max conversion time. It features single-chip construction and provides an SMD (standard military drawing) that simplifies device selection and qualification. Its maximum integral nonlinearity is ±0.5 LSB, and its maximum differential nonlinearity equals ±1 LSB. The device provides a power dissipation of 135 mW typ

and includes an on-chip reference and an oscillator-clock. You can obtain it in a 24-pin ceramic DIP or in a 28-terminal PLCC. From $135.50 (100).

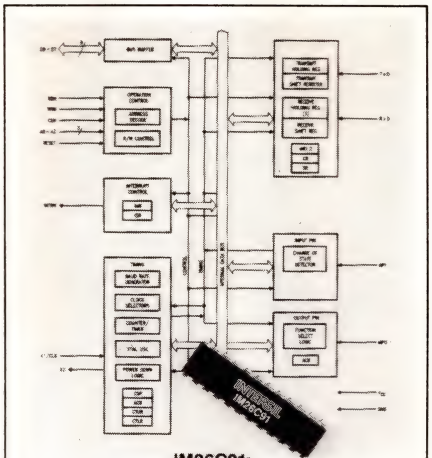
Analog Devices, Literature Center, 70 Shawmut Rd, Canton, MA 02021. Phone (617) 935-5565. TWX 710-394-6577.

Circle No 354

CMOS UART

- *Pin compatible with SCC2691*
- *Programmable operating speeds*

The IM26C91 UART, a pin-for-pin replacement for the SCC2691, has 1.5-µm CMOS fabrication that permits monolithic construction and 300-mil-wide packaging. A feature unique to the device is its ability to eliminate overrun errors, according to the vendor. A 4-level FIFO on the front end has a handshaking capability that disables a remote UART transmitter when the receiver buffer is full. Useful for dual-speed applications, the UART lets you program operating speeds—from an internal counter/timer or an external 1× or 16× clock—in 18 fixed baud rates ranging from 50k to 38.4k baud. The µP- and TTL-compatible device is a registered UART that provides full-duplex operation and operates from a 5V supply. It comes in a 24-pin plastic DIP or a 28-pin surface-mount PLCC. $5.45 (100).



IM26C91:

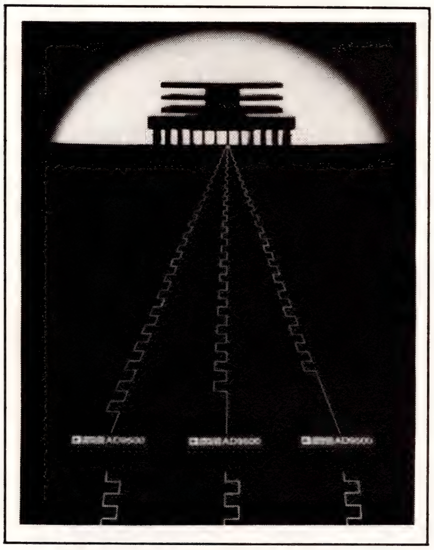
GE Solid State, 10600 Ridgeview Ct, Cupertino, CA 95014. Phone (408) 996-5703.

INQUIRE DIRECT

PROGRAMMABLE DTC

- *Digital-to-time converter delays digital pulses*
- *2.5-nsec to 100-µsec delays are possible*

Programmed with an 8-bit digital word, the AD9500 provides precise delay of digital signals. It receives, delays, and then retransmits a digital pulse. The delays range from 2.5 nsec to 100 µsec with resolution to 10 psec. The device includes an 8-bit DAC, a differential analog-input stage, a timing control circuit, an output drive stage, and a voltage reference on a single monolithic



chip. It operates from 5 and −5.2V supplies. Depending on package options and the temperature grade, $16 to $40 (100).

Analog Devices, Literature Center, 70 Shawmut Rd, Canton, MA 02021. Phone (919) 668-9511. TWX 710-394-6577.

Circle No 356

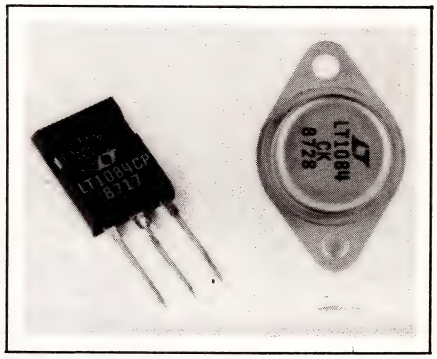
6-BIT ATTENUATOR

- *Selectable attenuation range of 0 to 15.75 dB*
- *Useful to 40 MHz*

The CDG4460J 6-bit, digitally controlled attenuator can operate at analog frequencies as high as 40 MHz. It's a hybrid circuit that contains three CMOS/DMOS ICs and 11 laser-trimmed resistors mounted on a thick-film ceramic substrate. The hybrid package can fit on 1 in^2 of a pc board. It has an attenuation range of 0 to 15.75 dB, selectable in increments of 0.25 dB. Designed for 75Ω systems, the device provides constant resistance for both the input and output regardless of the attenuator setting. An onboard data latch lets you set predetermined attenuation levels or to recall settings from memory. You can use the CDG4460J in in-circuit attenuators for equipment operating in the frequency range of 10.7 to 30 MHz. $39.50.

Topaz Semiconductor, 1971 N Capitol Ave, San Jose, CA 95132. Phone (408) 942-9100. TWX 910-338-0025.

Circle No 357



VOLTAGE REGULATOR

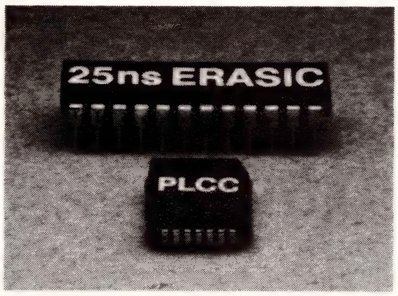
- *5A adjustable, 3-terminal type*
- *1.5V max dropout*

The LT1084 voltage regulator is pin compatible with existing 3-terminal regulators such as the LM138, but the LT1084's maximum dropout of

1.5V is approximately 50% lower. During manufacturing the device is trimmed to adjust the reference-voltage accuracy to 1%. It has on-chip protection against short circuits and shuts down if the temperature exceeds 165°C. The typical line regulation is 0.015% and the load regulation is 0.1%. The device is available in TO-3 metal cans and TO-247 plastic packages. TO-247, $5 (100).

Linear Technology Corp, 1630 McCarthy Blvd, Milpitas, CA 95035. Phone (408) 432-1900.

Circle No 358



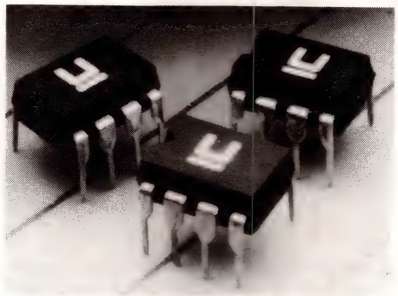
EEPLD

- *High-density CMOS*
- *25-nsec speed*

The XL78C800-25 Erasic (electrically reprogrammable ASIC) has a 10-nsec I/O delay and a 15-nsec internal delay for signals routed through internal feedback levels. It is pin compatible with many PAL-type PLDs, but draws less current (45 mA max vs 180 mA for bipolar PLDs). The device is configured as an uncommitted plane of NOR gates with 10 user-configurable macrocells, each with a JK flip-flop. You can configure 42 levels of internal logic without going off chip, thus allowing the integration of complete systems into a 24-pin package. The Erasic is available in three speed versions: XL78C800-25, $17; XL78C800-35, $12; XL78C800-45, $9.25 (100).

Exel Microelectronics Inc, 2150 Commerce Dr, San Jose, CA 95131. Phone (408) 432-0500. TLX 171339.

Circle No 359



DUAL FET DRIVER

- *Operates at high speed*
- *Features TTL compatibility*

The UC3709 power driver provides fast turn-on and turn-off for the capacitive gates of power MOSFETs. Manufactured in a high-speed Schottky process, the device features totem-pole outputs that can source or sink drive currents to 1.5A with minimal cross-conduction current spikes. It is TTL compatible at the input and has an output stage that can swing over a 30V range. Additional features include thermal-shutdown protection and under-voltage lockout. The device comes in either an 8-pin ceramic DIP or an 8-pin plastic minidip. $1.89 (100).

Unitrode Integrated Circuits, 7 Continental Blvd, Merrimack, NH 03054. Phone (603) 424-2410.

Circle No 360

QUAD OP AMP

- *8V/μsec slew rate*
- *6.5-MHz gain bandwidth*

The OP-471GP quad op amp features a slew rate of 8V/μsec and a gain-bandwidth product of 6.5 MHz. It has a 1-mV typ input-offset voltage and 1.8 mV max. The open-loop gain exceeds 300,000, and the input bias current is 60 nA max, thus minimizing dc error caused by source resistance. The device's common-mode rejection is 95 dB, and its power-supply rejection ratio is 5.6 μV/V max. It conforms to the industry-standard quad pinout and is specified over the commercial temperature range. $5.50 (100).

Precision Monolithics Inc, Box

Text continued on pg 252

TEK 4200 SERIES TERMINALS

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In Oregon, 1-235-7202.

Comparison of Graphics Terminals

	TEK	DEC	IBM
DEC Host Compatible	Yes	Yes	No
IBM Host Compatible	Yes	No	Yes
Multiple Active Sessions	Yes	Yes	No
Tek 4010-4100 Command Set	Yes	No	No
Segments	Yes	No	No
True Zoom and Pan	Yes	No	No
IBM GDDM (Graphical Data Display Manager) Support	Yes	No	Yes
Graphics Addressability of 4096 × 4096	Yes	No	No
VT200 Alphanumerics	Yes	Yes	No
Background Hardcopy	Yes	No	No
Separate Graphics and Alphanumeric Regions	Yes	No	Yes

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58020, Santa Clara, CA 95052. Phone (408) 727-9222. TLX 713719541.

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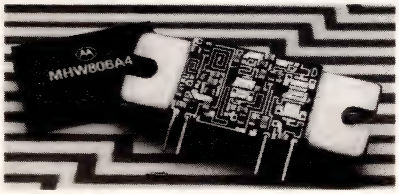


RF MODULE

- *For cellular radios*
- *Minimum output power of 6W*

The MHW806A comes in four versions that cover the cellular frequency spectrum from 806 to 950 MHz. All versions have a minimum output power of 6W and feature stable performance in output power over a 35-dB range. The module operates from a 12.5V supply and has input and output impedances of 50Ω. The four versions are specified according to bandwidth and gain. MHW-806A1, $32; MHW806A2, $36.50; MHW806A3, $39; MHW806A4, $43. (100).

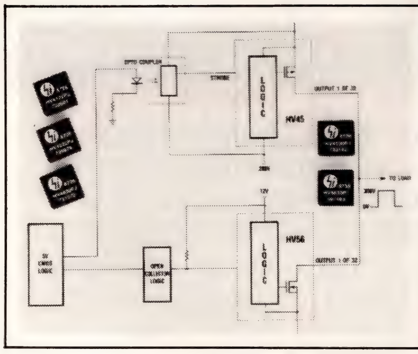
Motorola Inc, Technical Information Center, Box 52073, Phoenix, AZ 85074. Phone (512) 928-6705.

Circle No 362

HV DRIVERS

- *Provide 32 open-drain outputs*
- *Complement N-channel devices for symmetrical driving*

You can use the HV41, 42, 45, and 46 P-channel drivers to complement the HV51, 52, 55, and 56 N-channel drivers in flat panel displays that require a symmetrical drive scheme. The devices are also suited for use in printers that require active pullup and pulldown functions to 300V. The HV41 and its reverse-



shift complement, the HV42, have 32 open-drain, 225V, P-channel outputs, each of which can source 80 mA. The outputs are controlled by a 4-MHz shift register that has output-enable and all-on functions. The HV45 and its reverse-shift complement, the HV46, have 32 open-drain, 300V, P-channel outputs, each of which can source 60 mA. The outputs are controlled by a 4-MHz shift register that possesses latches, polarity control, and blanking control. The blanking control creates an all-off condition without affecting

the shift-register or latch data. The polarity control inverts the data from the latch or the blanking control. You can order the devices in 44-pin PLCCs or in hermetic 44-pin ceramic packages. From $6.34 (1000).

Supertex Inc, 1225 Bordeaux Dr, Sunnyvale, CA 94088. Phone (408) 744-0100. TWX 910-339-9388.

Circle No 363

PARITY ICs

- *16-bit parity at throughput rates to 30 MHz*
- *Cascadable for greater word lengths*

The PC74HC7080 and PC74HCT7080 parity generator/checker ICs provide a single-chip solution to generating parity for 16-bit data words. The HC version has CMOS-compatible inputs and outputs and operates from a supply voltage of 2 to 6V; the HCT version has TTL-compatible inputs and outputs and operates from a supply voltage of 4.5 to 5.5V. Both devices have a typical propagation delay of 33 nsec, allowing you to use them in systems that operate at 30 MHz. For longer word lengths you can cascade the devices—two devices can generate 32-bit parity at 20 MHz. They provide an even or odd parity output that can be active high or active low. Operating from a 5V supply into a 50-pF load at 20 MHz, the devices consume an active power of approximately 17 mW. Their quiescent supply current is 8 μA. Both ICs have an operating temperature range of −40 to +125°C and are available in 20-pin DIPs or small-outline packages. Approximately Gld 5.25 (100).

Philips, Components Div, Box 523, 5600 AM Eindhoven, Netherlands. Phone (040) 757189. TLX 51573.

Circle No 364

Signetics Corp, 811 E Arques Ave, Sunnyvale, CA 94088. Phone (408) 991-4571.

Circle No 365

VOLTAGE TRIPLER

- *Lets you power CMOS logic from an alkaline-cell battery*
- *Has a fully regulated, programmable output voltage*

By employing charge-pump techniques, the SL6670 provides voltage tripling without the use of external inductors or transformers. It features a fully regulated output and is programmable via an external resistor, allowing it to maintain a constant output voltage over a variety of input and load conditions. The device runs off supply voltages as low as 0.95V. You can program the device's output voltage in the range of 0.9 to 8V; it can achieve voltage conversion efficiencies of 99%.

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Wilmington, MA 01887, Phone: (617) 658-0880
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*USA price list

CIRCLE NO 124

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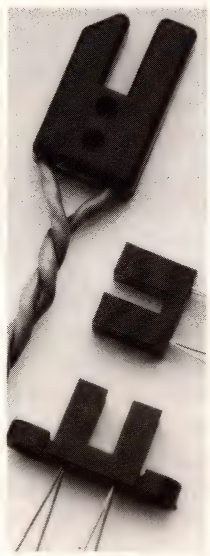

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CIRCLE NO 125

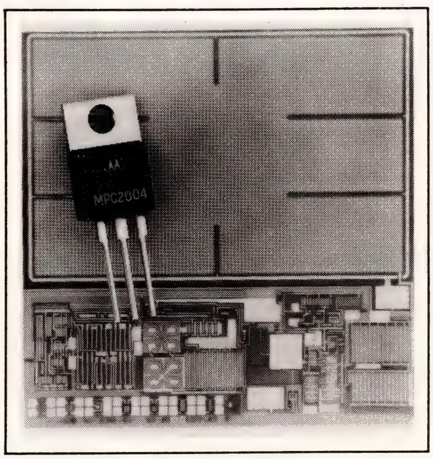
Other features of the device include a programmable oscillator to control the switching frequency, and a battery-low flag output. You can obtain samples enclosed in a 14-pin small-outline, surface-mount package for £2.02 (1000).

Plessey Semiconductors Ltd, Cheney Manor, Swindon, Wiltshire SN2 2QW, UK. Phone (0793) 36251. TLX 449637.

Circle No 366

Plessey Semiconductors, 9 Parker, Irvine, CA 92718. Phone (714) 472-0303.

Circle No 367



SMARTMOS CIRCUITS

- *Provide overvoltage and overtemperature protection*
- *For 5, 12, and 15V power buses*

The MPC2004, 2005, 2011, 2012, 2014, and 2015 comprise a family of six protection circuits rated at 7.5 and 15A and split into three voltage groups of 5, 12, and 15V. Combining CMOS logic with a silicon controlled rectifier (SCR), these SmartMOS devices provide overvoltage and overtemperature protection for sensitive systems by crowbarring the power bus if voltage or temperature exceeds a preset level. The devices feature a pin that allows you to increase the trip voltage or vary the transient response. Because of low dissipation in the off state, the junction temperature of each device essentially equals the case temperature of the TO-220 package. The 7.5A MPC2004 (5V), 2011 (12V), and 2014 (15V) cost $1.45; the 15A 2005 (5V), 2012 (12V), and 2015 (15V) cost $1.75 (100).

Motorola Inc, Technical Info Ctr, Box 52073, Phoenix, AZ 85072. Phone (512) 928-6705. Delivery, stock to eight weeks ARO.

Circle No 368

REGULATING PWMs

- *Low-drift 5V bandgap reference*
- *Double-pulse suppression logic*

The SG1526B/2526B/3526B Series PWMs offer improved performance over the industry-standard SG1526 Series. Pin-compatible with the SG1526, the SG1526B provides a bandgap reference circuit for im-

Switching Times

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Innovations In Switching Technology

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MAGLATCH NOW CMOS COMPATIBLE

Maglatch Low Power and Indestructible Memory Ideal For Aircraft and Space

Teledyne Relays has introduced a new CMOS compatible Centigrid® version of its popular TO-5 Maglatch relay. This 122C relay is set with a short pulse of coil voltage and retains its state until it is reset, even if the system power fails or is shut off. Since no holding power is required, the 122C is also ideal where power is at a premium. A power FET driver in each input enables direct relay interfacing with CMOS and most other logic families. In addition, its small footprint is well-suited to the newest high-density printed circuit boards. For RF switching applications, the inherently low intercontact capacitance of the 122C provides high isolation and low insertion loss up through 1GHz. The 122C is built to meet the requirements of established reliability mil specs MIL-R-28776 and can be screened to P level. Teledyne's non-latching CMOS compatible relays introduced earlier are already QPL approved to MIL-R-28776/7 and /8.

2 Amp TO-5 Relay In Squib Firing Application

The new 2 amp version of Teledyne's proven TO-5 relay is finding new uses, including squib firing applications. The 212 Series TO-5 relay combines the small package—only .390 inches high—and the time-tested Teledyne reliability which are required for squib firing and other military applications. The 212 Series TO-5 relay is also ideal for controlling small motor loads, lamp loads, and capacitive loads, where current surge at turn-on and turn-off run as high as 2 amps. An innovative proprietary contact system, called TELESIUM,™ makes the higher power level possible and also gives the 212 Series a resistive load rating up to 2 amperes for 100,000 operations.

Teledyne Solid State Introduces New ATE Relay

New C66 Solid State Relay was developed for use in automotive diagnostic test equipment, but other applications are emerging. When this device is turned off it has an extraordinarily low leakage (50 nanoamps). The hermetically sealed units are only 0.458″ square and 0.190″ high and have current ratings of from ±0.3 amp at ±380 volts to ±1 amp at ±200 volts. They are available from Teledyne Solid State now.

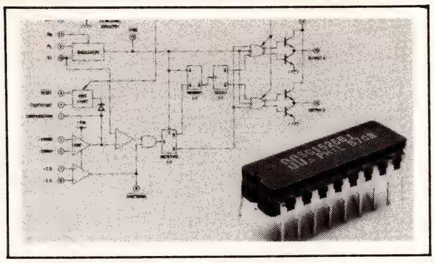
For More Information

Teledyne Relays, 12525 Daphne Ave., Hawthorne, California 90250 • (213) 777-0077/**European Headquarters: W. Germany:** Abraham Lincoln Strasse 38-42, 6200 Wiesbaden/ **Belgium:** 181 Chaussee de la Hulpe, 1170 Brussels/ **U.K.:** The Harlequin Centre, Southall Lane, Southall, Middlesex, UB2 5NH/ **Japan:** Taikoh No. 3 Building, 2-10-7 Shibuya, Shibuya-Ku, Tokyo 150/ **France:** 85-87 Rue Anatole-France, 92300 Levallois-Perret.

Teledyne Supplies Hi-Rel Space Programs

Teledyne's dedication to reliability has made its TO-5 relay the choice of virtually every space program in the Free World. Expanded NASA and Military use of Teledyne's TO-5 for space applications reliability is vertical integration. All piece parts are produced, and critical manufacturing processes are controlled in-house. Teledyne's dedicated "Blue Traveler" hi-rel production line provides utilizing 2-micron small particle cleaning prior to hermetic sealing. All hi-rel TO-5s must pass rigorous functional and environmental screening tests to assure "spaceworthiness." An asynchronous miss test

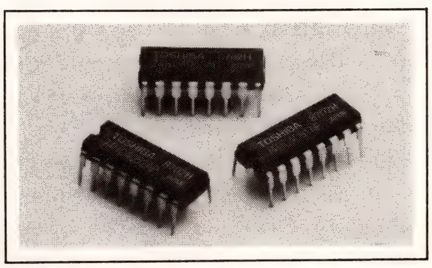
CIRCLE NO 126



proved regulation and drift characteristics, and an improved double-pulse suppression logic for higher-speed operation. It also features an improved undervoltage lockout circuit and an output driver that features a shoot-through current of <100 mA. A tighter tolerance on soft-start time, programmable deadtime, digital current limiting, and faster rise and fall times provide further enhancements. The series operates from a supply voltage of 8 to 35V and is designed for single-ended or push-pull switching regulators. It provides individual types specified for commercial, industrial, or military temperature ranges. The SG3526BN in a plastic package, $2.80 (100).

Silicon General, 11861 Western Ave, Garden Grove, CA 92641. Phone (714) 898-8121. TWX 910-596-1804.

Circle No 369



ANALOG MULTIPLEXERS

- *Have 4-nsec propagation delay*
- *Feature 4-μA current drain*

Members of the TC74HC4051AP line of analog multiplexers, which draw 4 μA of current and feature a 4-nsec typ propagation delay, operate at higher speeds than do members of the original 74HC logic family. The devices meet or exceed JEDEC Standard 7A requirements. The 8-channel 4051, the dual 4-channel 4052, and the triple 2-channel 4053 versions are pin- and function-compatible with 4051, 4052, and 4053B parts. Housed in 16-pin DIPs, the devices cost $0.96 (100).

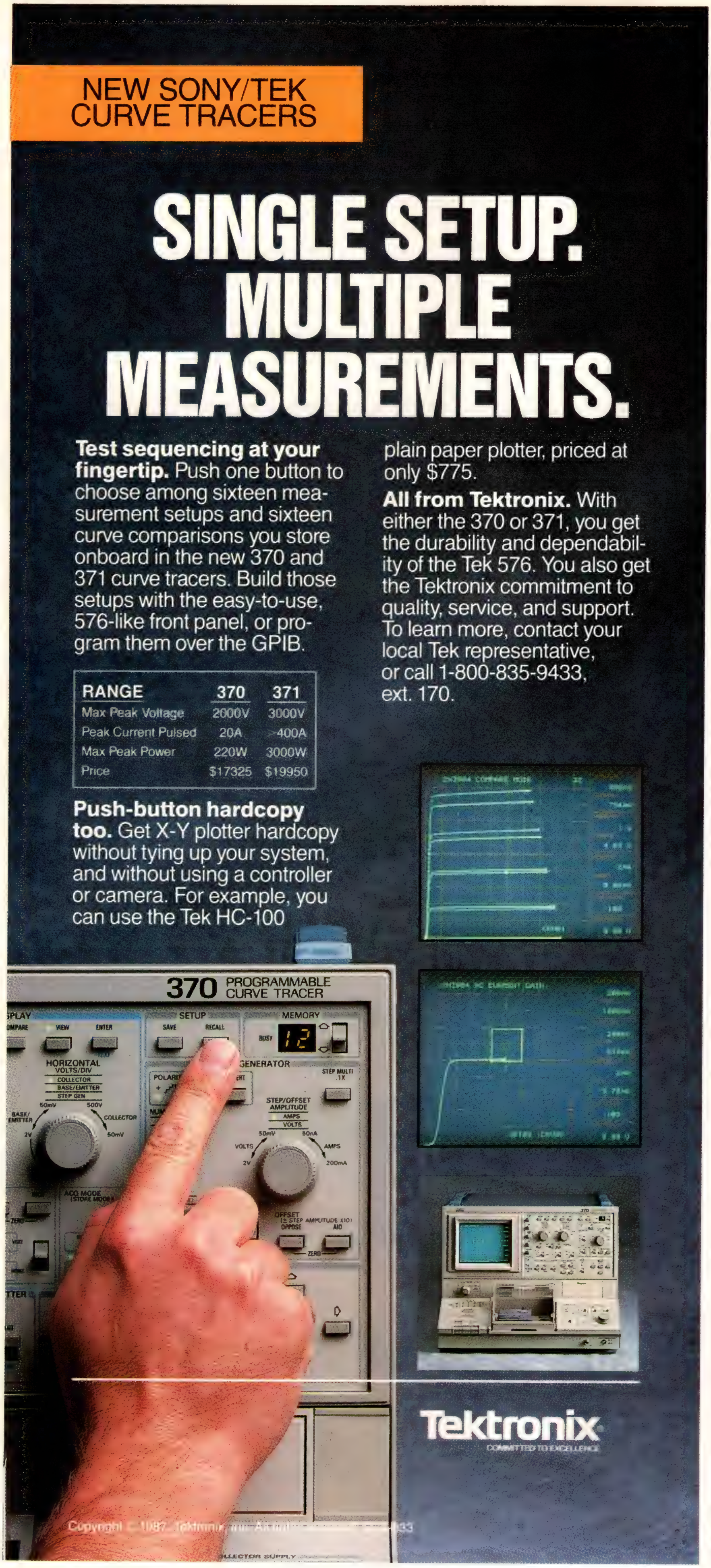
Toshiba America, 2692 Dow Ave, Tustin, CA 92680. Phone (714) 832-6300.

Circle No 370

CLOCK DRIVER

- *Drives capacitive loads*
- *Slew rate of 2V/nsec into a 100-pF load*

Capable of high-speed switching into capacitive loads, the SP9010 CCD clock driver can drive the clock inputs of CCD delay lines. You can also use it to drive other low-imped-



ance loads—for example, fiber-optic transmission LEDs or high-speed digital transmission lines. The device generates two symmetrical complementary outputs. Operating into a 100-pF load, it can deliver a 12V, 25-MHz output signal that has a slew rate of 2V/nsec. The device's inputs are CMOS and TTL compatible and incorporate OR gates that allow you to generate continuous or burst-mode clocks. £2.99 (1000).

Plessey Semiconductors Ltd, Cheney Manor, Swindon, Wiltshire SN2 2QW, UK. Phone (0793) 36251. TLX 449637.

Circle No 371

Plessey Semiconductors, 9 Parker, Irvine, CA 92718. Phone (714) 472-0303. TLX 701464.

Circle No 372

GATE ARRAYS

- *6000- and 10,000-gate devices*
- *Provide 0.8-nsec max gate delay*

The 6000-gate μPD67060 and the 10,000-gate μPD67101 feature the same internal cell structure and block library as the vendor's first-generation, 600-to-3000-gate BiCMOS devices, but use only a single output buffer to provide 24 mA of drive. They feature a gate delay of 0.45 nsec typ and 0.8 nsec max. Both devices use either CMOS or TTL interfaces. The gate arrays come in 68- or 84-pin PLCCs, in 120-to-160-pin plastic flat packages, or in 72-to-280-pin ceramic or plastic pin grid arrays. The NRE (nonrecurring engineering) charges range from $45,000 to $65,000 and cover costs through the prototype stage. The unit prices for the devices equal roughly $0.002 per gate.

NEC Electronics Inc, Box 7241, Mountain View, CA 94039. Phone (415) 960-6000. TWX 910-379-6985.

Circle No 373

TANTALUM CHIPS: KEMET® Is The Source.

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Take a close look at the unique, production-boosting features of the T491 Series surface mount capacitor from KEMET. It's an excitingly different molded tantalum chip design that can increase your production efficiency as it boosts your product reliability:

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CIRCLE NO 131

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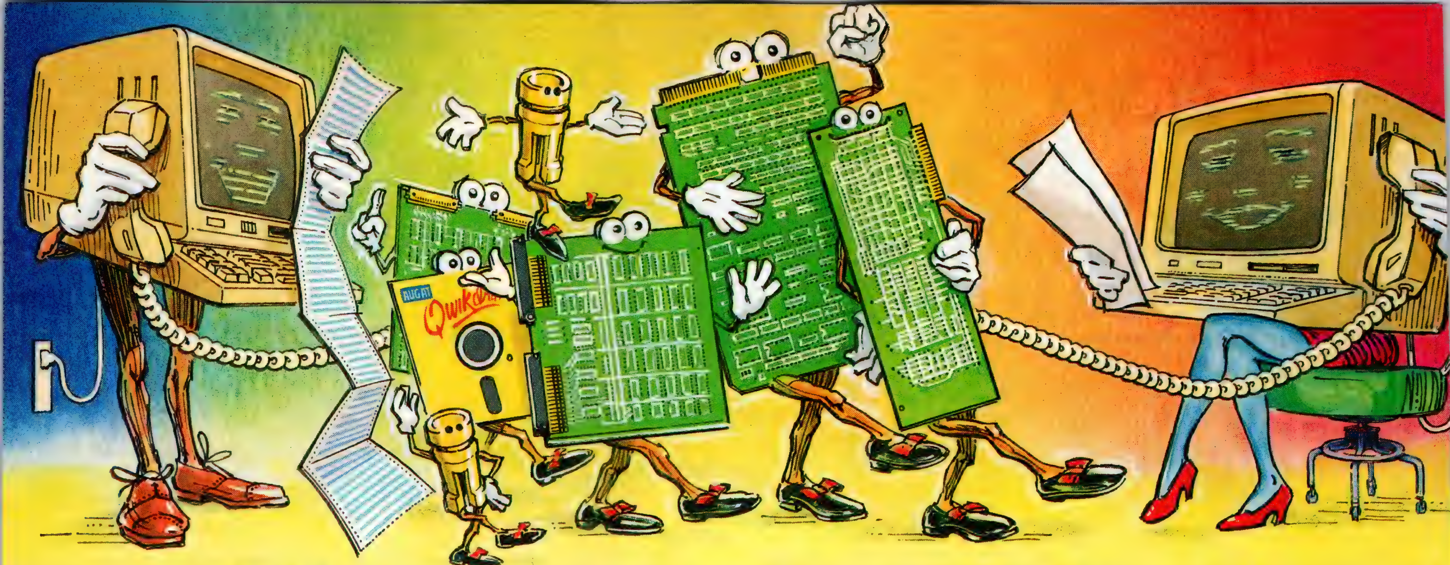

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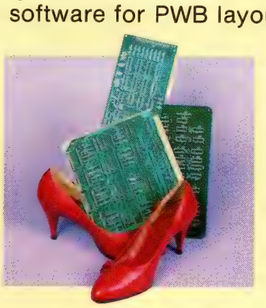

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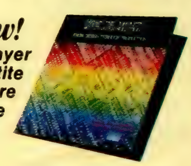

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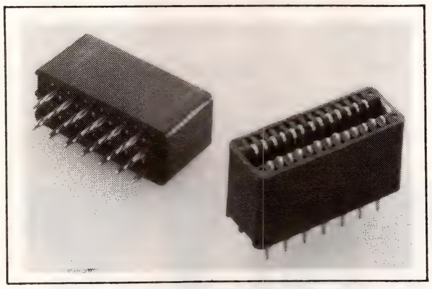
CIRCLE NO 129

COMPONENTS & POWER SUPPLIES

CONNECTORS



- *Minimize pc-board real-estate requirements*
- *Feature 94V-0 flammability rating*

Mini-Edge pc-board connectors have 0.35-in. profiles and 0.050-in. center-to-center pin spacings. Each of the connectors features 26 contacts arranged in two 13-position rows and gold-over-nickel plating on the card-edge contact areas; the individually replaceable beryllium-copper contacts apply continuous normal force to 0.022-in. plated-through holes and are arranged in pairs to accommodate double-sided pc boards. The connectors' 94V-0-rated polyester housings resist the high temperatures of flow soldering. Their molded-in standoffs facilitate cleaning processes. $5.83 (1000). Delivery, four to six weeks ARO.

Amp Inc, Box 3608, Harrisburg, PA 17105. Phone (717) 564-0100.

Circle No 376

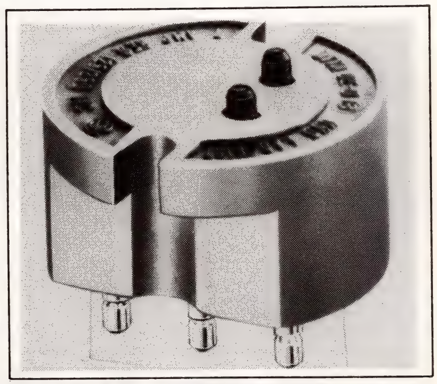
KEYPAD

- *Compatible with all PC- and MS-DOS machines*
- *Interfaces with an RS-232C port*

Although the 22-position Touchstone 3 numeric keypad was designed especially for laptop computers, it will work with larger portables and desktop PCs as well. In fact, you can read its standard ASCII character codes into any RS-232C port. The unit comes with RAM-resident software that lets you use the keypad and main keyboard simultaneously. The keypad layout conforms to standard calculator arrangements and includes math keys, cursors, page controls, backspace, enter, escape, and function keys as well as the 10 numeric keys. The CMOS circuitry runs on power from the serial port. The low-profile keypad features full-travel keyswitches that have tactile feedback. $129.95.

Touchstone Technology Inc, Box 24954, Rochester, NY 14624. Phone (716) 235-8358.

Circle No 375



ROTARY SWITCHES

- *Handle 7A loads*
- *Come with silver, gold-flashed silver, or gold contacts*

U3-018 subminiature rotary switches feature dual snap-action contact configurations. The contacts have a 25-mΩ max contact resistance and handle dry circuit to 7A loads. The switches come with silver, gold-flashed silver, or gold contacts. The termination options include 0.58-in. quick-connect, single- and double-turret, wire-wrap, and pc-board type terminals. The switches measure 0.562×0.365 in. and are UL listed and CSA certified. $5.40 (1000). Delivery, four to six weeks ARO.

Otto Controls, 2 E Main St, Carpentersville, IL 60110. Phone (312) 428-7171.

Circle No 377

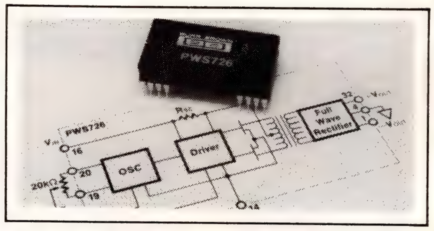
DISPLAYS

- *Feature a −55 to +100°C operating range*
- *Provide 0.15- or 0.2-in. character heights*

MSD2000/2300 and ISD2000/2300 4-character, 5×7 dot-matrix displays feature CMOS circuitry for low power consumption. Suited to military and industrial environments, they are housed in hermetically sealed 12-pin DIPs and operate over a −55 to +100°C range. The MSD2000 and ISD2000 displays provide 0.15-in. characters, and the MSD2300 and ISD2300 displays offer 0.2-in. characters. You can specify a red, yellow, green, or high-efficiency red LED. Each display package includes two CMOS shift registers (7 bits per character) with built-in row drivers. The registers drive 28 rows, letting users define customized fonts. You can easily cascade the packages in either the X or Y direction to develop multiple character displays. You can also obtain yellow, green, or high-efficency red, 0.2-in.-character displays that are viewable in direct sunlight. $58 to $196 (100).

Siemens Components Inc, Optoelectronics Div, 19000 Homestead Rd, Cupertino, CA 95014. Phone (408) 257-7910.

Circle No 378



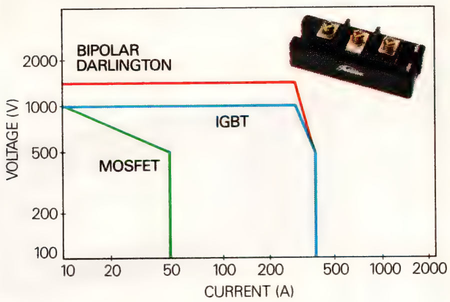
DC/DC CONVERTER

- *Has current-sensing protection against thermal damage*
- *Lets you synchronize as many as eight converters*

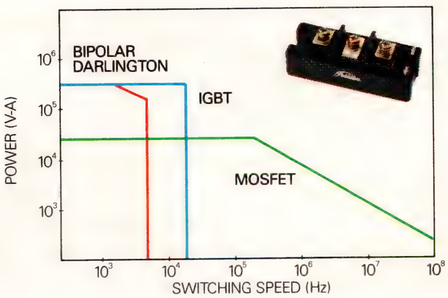
The PWS726 dc/dc converter features an oscillator, a driver circuit, dc switches, a transformer, internal filter capacitors, and a rectifier housed in a 32-pin DIP. It supplies ±7 to ±18V dc outputs at ±40 mA. Galvanic input/output isolation is 100% tested at 800V dc and guaranteed to 2500V rms continuous, 3500V rms momentary. Other features include a 1.2 μA leakage current and a 9-pF leakage capacitance. A separate synchronous connection lets you frequency-synchronize as many as eight converters, while an Enable input provides flexible control over outputs for power conversion and sequencing. To protect the switches and prevent high inrush currents during the turn on, a soft-start/driver design ensures that the oscillator is fully operational before either MOSFET driver turns on. Input current sens-

IGBTs. The latest comparisons.

Compare Power



Compare Speed



The choice is now obvious when you require both power and switching speed in your power systems. Insulated Gate Bipolar Transistors (IGBTs) offer both.

Similar to Bipolar, IGBTs have high conductivity with faster switching speeds ($t_f = 0.5\mu S$ typ). And like MOSFETS, IGBTs have high input impedance/high speed with lower on-resistance (as low as $8m\Omega$).

So now, for applications like low-noise inverters and servo-motor drives, there really isn't any reason to compromise. The solution you've been looking for is available: IGBT. The performance combination that doesn't make you give up one thing to get another.

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Compare Selection

IGBT (Insulated Gate Bipolar Transistor) Selection Guide

CONNECTION			MAXIMUM RATINGS										
				COLLECTOR CURRENT I_C (A)									
	CIRCUIT	SYMBOL	V_{CES} (v)	8	15	25	50	75	100	150	200	300	400
1 IN 1		GT*	500		GT15H101*	GT25H101*							
			1000	GT8N101*	GT15N101*								
		BS	500		MG15H1BS1	MG25H1BS1	MG50H1BS1	MG75H1BS1	MG100H1BS1				
			1000		MG15N1BS1	MG25N1BS1	MG50N1BS1	MG75N1BS1					
			1200	UNDER DEVELOPMENT									
		US	500									MG300H1US1	MG400H1US1
			1000								MG200N1US1	MG300N1US1	
			1200	UNDER DEVELOPMENT									
2 IN 1		YS (CS)	500			MG25H2CS1 MG25H2YS1	MG50H2YS1	MG75H2YS1	MG100H2YS1	MG150H2YS1	MG200H2YS1		
			1000		MG15N2YS1	MG25N2YS1	MG50N2YS1	MG75N2YS1	MG100N2YS1	MG150N2YS1			
			1200	UNDER DEVELOPMENT									
6 IN 1		ES	500		MG15H6ES1								
			1000		MG15N6ES1								
			1200	UNDER DEVELOPMENT									

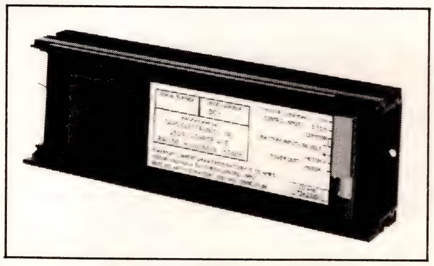
*TO-3P PACKAGE ▒ = UNDER DEVELOPMENT

CIRCLE NO 128

ing protects both the converter and the load from possible thermal damage by limiting the output fault currents. \$27.70 (100).

Burr-Brown Corp, Box 11400, Tucson, AZ 85734. Phone (602) 746-1111. TWX 910-952-1111.

Circle No 379



MOTOR CONTROLLER

- *Features 93% efficiency*
- *Regulation of 0.2% for varying load and battery voltage*

The DC-3610 motor controller drives a 24V motor from a 36V battery with an efficiency of 93%. The output current is limited to 10A and the output voltage ripple is less than 100 mV rms at 125 kHz; these specifications correspond to a 1.0001 form factor. A 0 to 5V input controls the voltage to the motor. A 5V regulated supply is available for use with potentiometer or op-amp control applications. The regulation specs at 0.2% max for varying load and battery voltage. \$195.

Zahn Electronics Inc, 2629 Lathrop Ave, Racine, WI 53405. Phone (414) 634-4300.

Circle No 380

POWER MOSFETs

- *Handle 11A currents*
- *Feature 170W max power dissipation*

The 500V IRFP448 and IRF448 power MOSFETs come in plastic and hermetic TO-3 packages, respectively. The IRFP448 has a 0.6Ω on-resistance, an 11A continuous current rating, a 44A pulsed drain current, a 170W max power dissipation, a ±20V gate-to-source voltage,

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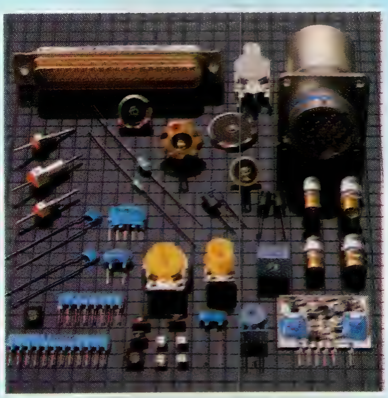

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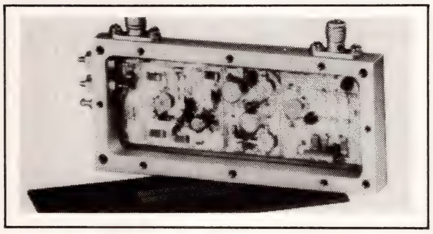
a 3.5 V/nsec dv/dt, and a 0.73°C/W thermal resistance. Respective figures for the IRF448 are 0.6Ω, 9.6A, 38A, 130W, 3.5V/nsec, and 0.94 °C/W. IRFP448, $6.69 (1000); IRF-448, $8.38. Delivery, nine weeks ARO.

International Rectifier, 233 Kansas St, El Segundo, CA 90245. Phone (213) 607-8899.

Circle No 381



IF LIMITER

- *Operates at 450 MHz with a 100-MHz p-p bandwidth*
- *Exhibits rapid limiting action at −15-dBm input levels*

The Model ICDT450 hybrid limiter/discriminator operates at 450 MHz with a p-p bandwidth of 100 MHz. It features a linearity of more than 6% over a linear bandwidth of 70 MHz. The unit is designed for 0-dBm inputs, but exhibits rapid limiting action at −15-dBm input levels. It provides at least 0.02V/MHz video output into a 93Ω load. Its input impedance specs at 50Ω, and the video baseband equals 25 MHz. With a rise time of 20 nsec, the unit is suitable for both CW and high-speed pulsed inputs. The unit draws 100 mA max from ±12V dc supplies. It is also available for operation at ±15V dc. $1350. Delivery, 90 days ARO.

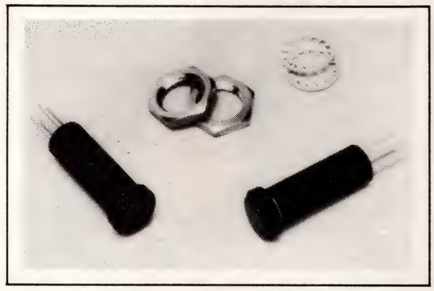
RHG Electronics Laboratory Inc, 161 E Industry Ct, Deer Park, NY 11729. Phone (516) 242-1100. TWX 510-242-1222.

Circle No 382

LED INDICATOR

- *Available in red, green, amber, and yellow*
- *Specs 400-mcd luminous intensity*

The Series 70 LED panel indicator features a mesh screen that suppresses RFI at frequencies ranging as high as 2 GHz. It's available in red, green, amber, and yellow. The indicator also has an anodized aluminum sleeve with a mounting surface that's designed for sure grounding contact. Fresnel lenses are available in flat or domed shapes in colors including tinted, smoked, or white for maximum on/off contrast. Additional specifications include a 400-mcd luminous intensity and an oper-



ating voltage in the 5V dc to 120V ac range. $18 (1000). Delivery, stock to five weeks.

Data Display Products, Box 91072, Los Angeles, CA 90009. Phone (800) 421-6815; in CA, (213) 640-0442. TLX 664690.

Circle No 383

POWER MOSFETs

- *Feature drain-to-source rating of 500V*
- *Have 2100-pF input capacitance*

The APT5025AN features a 500V drain-to-source voltage, a ±30V max gate-to-source voltage, an 18A continuous drain current, and a 72A pulsed drain current. Its power dissipation equals 180W at 25°C, and its operating range spans −55 to +150°C. The APT4525AN has a 450V drain-to-source voltage; all of its other specs match those of the 5025AN. The input capacitance for both devices equals 2100 pF. You

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For more information contact NCR Power Systems, 3200 Lake Emma Road, Lake Mary, FL 32746-3393.
Telephone 800/327-7612, in FL 407/323-9250

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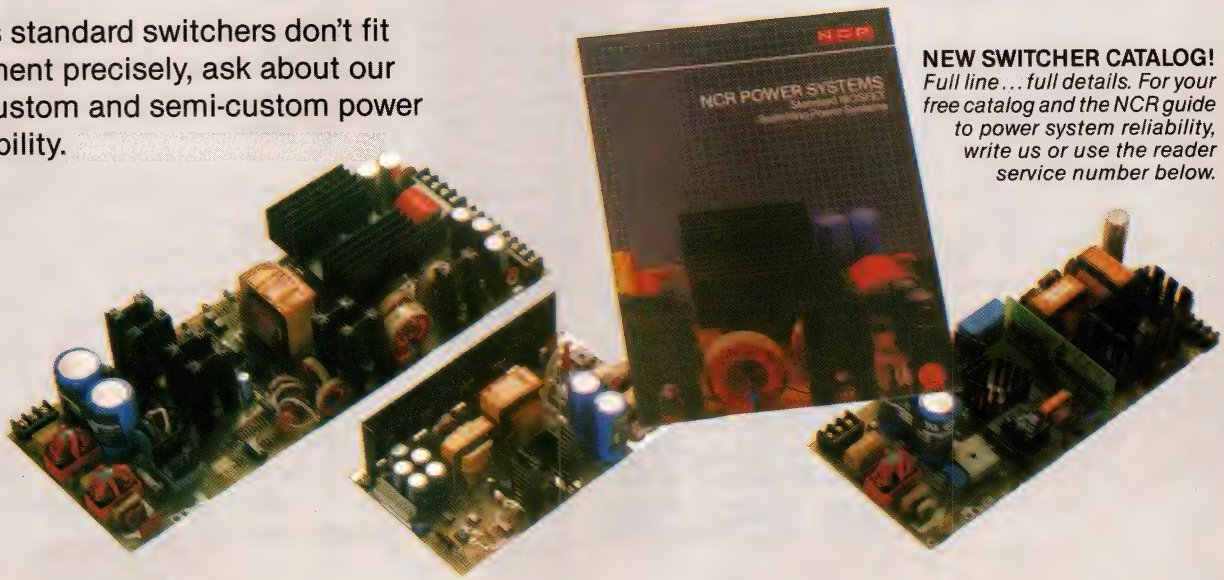

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can obtain each device in a TO-3 package or in die form. Military versions, tested in accordance with MIL-S-19500, are available. APT-5025AN, $22 (1000); APT4525AN, $19.80.

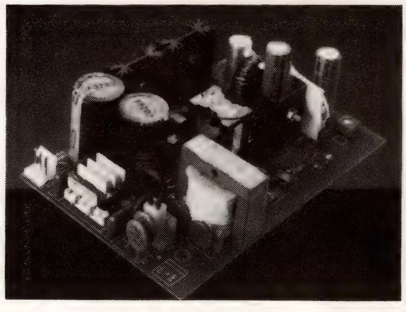
Advanced Power Technology, 405 SW Columbia St, Bend, OR 97702. Phone (503) 382-8028.

Circle No 384

POWER SUPPLY

- *Operates nonderated to 70°C*
- *Meets CSA, FCC, and MIL-STD-810C standards*

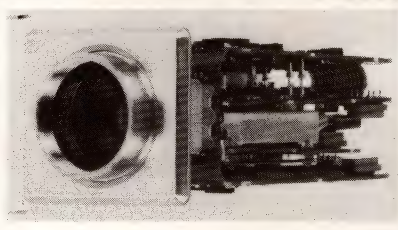
The Tron Series open-frame switching supply provides 31W of power in a 70°C operating environment without derating. It delivers 5V at 2.2A, 12V at 1.5A, and −12V at 100 mA.



Its switching frequency equals 100 kHz, and its efficiency specs at 75%. The regulation figures range from ±0.25 to ±0.75% for line and ±1 to 3% for load. The supply is UL recognized and meets CSA, FCC, and MIL-STD-810C (vibration and shock) standards. $80. Delivery, stock to eight weeks ARO.

Wells-Gardner Electronics Corp, 2701 N Kildare Ave, Chicago, IL 60639. Phone (312) 252-8220. TLX 253286.

Circle No 385



CAMERA ASSEMBLY

- *Produces a 525- or 625-line video output*
- *Requires only a lens and chassis to produce a complete camera*

You only need to add a chassis and lens to this solid-state image sensor assembly to produce a black-and-white video camera suitable for surveillance or machine-vision systems. The assembly, which includes the solid-state image sensor and drive, preprocessing, video-processing, and power-supply circuitry, is available in versions that operate to 525-line EIA or 625-line CCIR TV standards. When operating in the noninterlaced mode, the unit produces a video signal with 610×244 (EIA version) or 604×294 (CCIR version) picture elements. When

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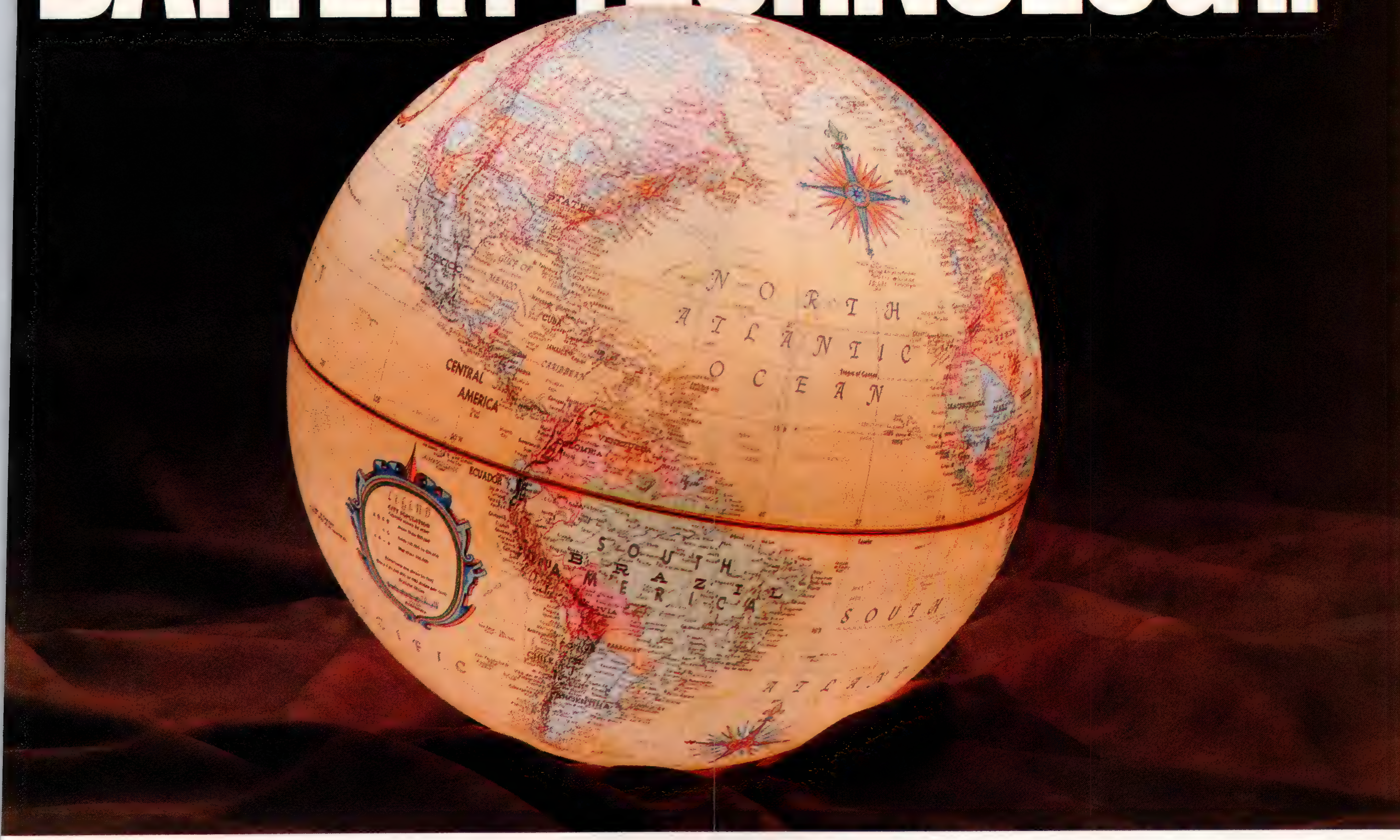

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CIRCLE NO 138

operating in the interlaced mode, the unit produces 610×488 (EIA) or 604×588 (CCIR) picture elements. Other selectable functions include compensation for gamma predistortion, automatic or computer-controlled gain, automatic iris control, and internal or external clock synchronization. The image sensor works in ambient light as low as 1 lux and still generates a useable picture at 0.5 lux. The signal-to-noise ratio is 46 dB, and the video bandwidth is 5.8 MHz for −6-dB gain. The output is a 1V p-p composite video signal. The assembly accepts standard C-mount lenses. The power consumption is a maximum of 165 mA from a single 12V supply. From DM 600 and DM 1300 (OEM qty).

Philips, Components Div, Box 523, 5600 AM Eindhoven, The Netherlands. Phone (040) 757189. TLX 51573.

Circle No 386

Amperex Sales Corp, Providence Turnpike, Slatersville, RI 02876. Phone (401) 762-9000.

Circle No 387

KEYBOARD

- *Offers IBM compatibility*
- *Tactile keyswitches for fast typing speed*

The 101-position KB-5161 keyboard is fully compatible with the IBM PC/XT, PC/AT, PS/2, and 386 computers. Each mechanical keyswitch features a tactile design for fast typing speed. All key caps are double injection molded with identifying alphanumerics molded in place for long life. The keyboard features a large L-shaped enter key, and double-wide backspace, shift, and caps-lock keys. The keyboard comes in a gray dust cover and operates from ±5V supplies. The full 101-key layout is on screen when you use the unit with IBM diagnostics. $89.

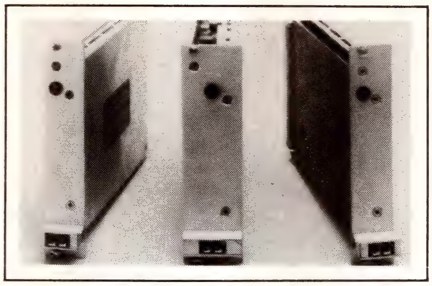
Chicony America Inc, 1641 W Collins Ave, Orange, CA 92667. Phone (714) 771-6151.

Circle No 388

DC/DC CONVERTERS

- *Designed for VME Bus applications*
- *Offer single and dual outputs ranging from 2 to 48V*

VMEC Series dc/dc converters are designed for VME Bus applications. They are available in 40 and 80W



versions housed in 3U-high packages that are 1 and 1.4 in. wide, respectively. Models are available with single and dual outputs ranging from 2 to 48V dc. The temperature coefficient measures 0.02%/°C, the switching frequency equals 125 kHz, and the ripple and noise spec at 1% or 50 mV, whichever is greater. Standard features include isolated outputs, EMI filtering, remote sensing, and overvoltage and overload protection. The line regulation equals ±0.1%, and the load regulation equals ±0.2%. 40W version, $127; 80W version, $169.

Power Pac Inc, Box 777, Norwalk, CT 06856. Phone (203) 866-4484.

Circle No 390

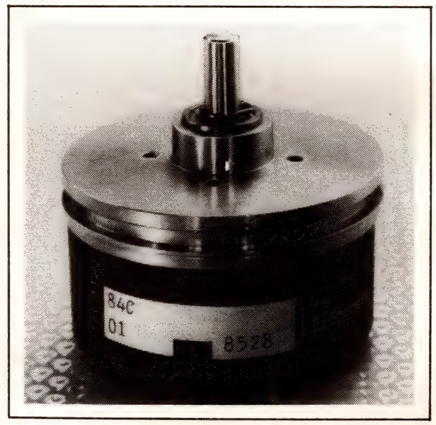
PRESSURE SENSOR

- *Fully compensated over a range of 10 to 85°C*
- *Eliminates the need for further signal amplification*

The Model XT silicon-based pressure transducer is fully compensated over a range of 10 to 85°C and is calibrated to an accuracy of ±0.25%. Operating from 5V dc excitation, the transducer provides an output of 0.5 to 4.5V dc, which eliminates the need for further signal amplification. The pressure ranges are 0 to 15 or 30 psia, and 0 to 7.5, 15, or 30- psig. A piezoresistive element diffused onto an etched silicon diaphragm does the pressure sensing. Laser-trimmed compensation resistors and an amplifier are housed in a package that mounts on pc boards. The transducer has an operating range of −40 to +125°C. $24 (OEM qty).

Data Instruments Inc, 100 Discovery Way, Acton, MA 01720. Phone (617) 264-9550. TLX 200081

Circle No 391



OPTICAL ENCODER

- *Provides resolutions to 1800 cycles*
- *Features TTL/CMOS-compatible outputs*

Model 84C optical incremental encoder provides resolutions to 1800 cycles and features a quadrature output plus an index marker pulse. Its operating frequency ranges to 100 kHz, and its outputs are TTL and CMOS compatible. Its standard features include a differential line driver and operating voltages ranging to 24V. The encoder cover meets UL 94V-0 requirements and the shielded cable is UL and CSA approved. $73 (100).

Litton Systems Inc, Encoder Div, 20745 Nordhoff St, Chatsworth, CA 91311. Phone (818) 341-6161.

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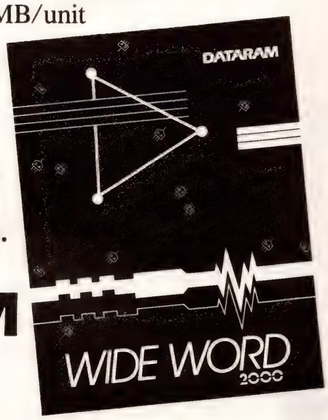

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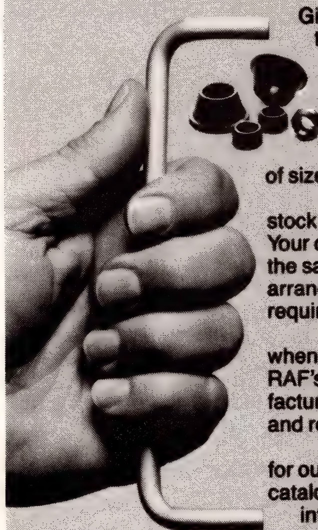

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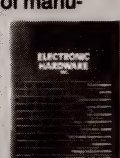

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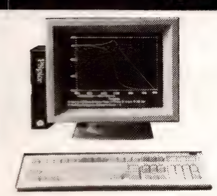

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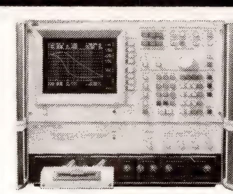

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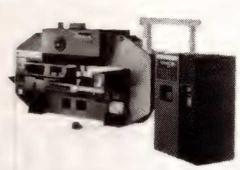
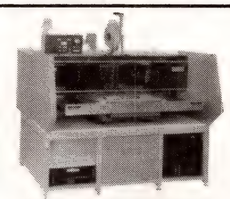


Sheet Metal by AMADA



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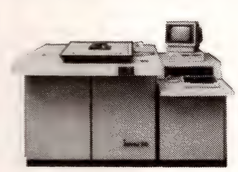

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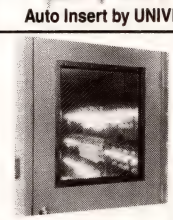

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ISOLATOR

- *Suitable for driving power MOSFETs*
- *Provides 370V input-to-output isolation*

The VB300 is suitable for isolating the gate-control voltage of power MOSFET transistors. To activate the output, you drive the device's differential inputs with antiphase square waves. Inside the device, these square waves are capacitively coupled to the output and rectified to provide a dc output voltage that is approximately 1.5V lower in amplitude than the input signal. The input-to-output isolation is rated at 370V. The inputs are compatible with CMOS logic and withstand a maximum signal amplitude of 20V. An integral resistor across the device's output discharges the output when the ac input signal is removed. $0.68 (1000).

SGS-Thomson Microelectronics, Via C Olivetti 2, 20041 Agrate Brianza, Italy. Phone (039) 65551. TLX 330131.

Circle No 393

SGS-Thomson Microelectronics, 1000 E Bell Rd, Phoenix, AZ 85022. Phone (602) 867-6100. TLX 249976.

Circle No 394

LED MODULES

- *Available in single-mode and multimode versions*
- *Operate at 1300 nm*

These edge-emitting LEDs operate at a nominal wavelength of 1300 nm and are available in FU-41SEL and FU-42SEL single-mode, and FU-31EL and FU-32EL multimode, versions. The FU-42SEL and the FU-32EL modules feature a thermoelectric cooler for temperature stabilization and couple 10 and 30 μW into single-mode and multimode fiber, respectively. The FU-41SEL and FU-31EL modules do not have a thermoelectric cooler, and their re-

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spective outputs into single-mode and multimode fiber are 6 and 20 μW. $460 to $690 (10).

Mitsubishi Electronics America Inc, Semiconductor Div, 1050 E Arques Ave, Sunnyvale, CA 94086. Phone (408) 730-5900.

Circle No 395

RESISTOR

- *Features resistance TC matching to ±5 ppm/°C*
- *Offers standard tolerance of 1%*

The Type WW silicone-coated wirewound power resistor features centerless ground-ceramic cores for optimum heat distribution and dissipation, and an all-welded construction that meets or exceeds MIL-R-26. The device is available in power ratings ranging from 0.4 to 12W at 25°C. Its standard resistance values range from 0.1Ω to 200 kΩ, and its standard tolerance equals 1%. Special features available on request include flame-resistant construction, resistance network packages designed for individual customer requirements, and TC matching and tracking to ±5 ppm/°C. The operating frequency range spans dc to 30 MHz. The resistors are available in bulk or tape-and-reel packaging. $0.25 to $0.85 (1000). Delivery, 12 weeks ARO.

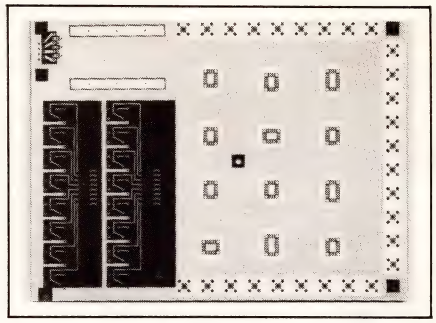
Allen-Bradley, Electronic Components Div, 1414 Allen-Bradley Dr, El Paso, TX 79936. Phone (800) 592-4888; in TX, (800) 292-4888.

Circle No 396

PROTOTYPING BOARD

- *Provides a way to evaluate high-speed GaAs devices*
- *Accommodates speeds to 5 GHz*

The MD12BRD 4-layer universal prototyping board provides an easy way to evaluate high-speed GaAs logic devices. It has nine sites for



16-pin flatpack ICs and three sites for 20-pin flatpack ICs, and provides easy access to power-supply and RF interconnections. The board is designed for applications reaching impedance levels as high as 50Ω and clock speeds as high as 5 GHz. It comes with application and assembly information, as well as a list of recommended capacitors, termination resistors, heat sinks, and RF interconnections. $100.

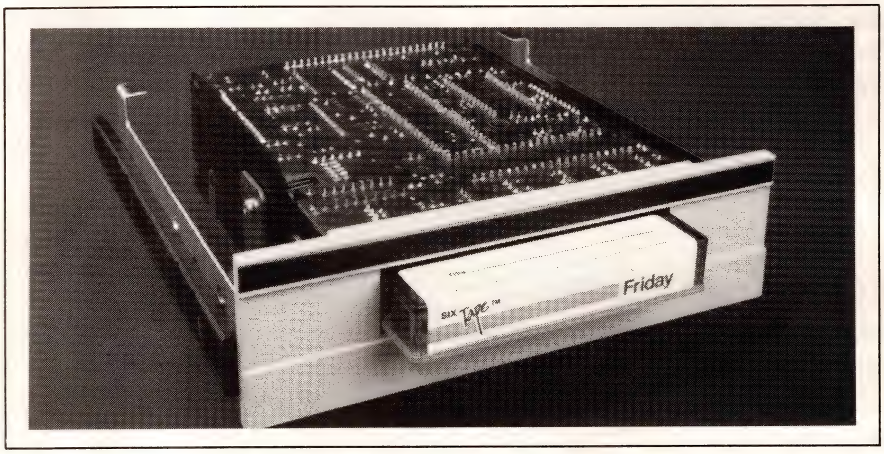
California Eastern Laboratories Inc, 3260 Jay St, Santa Clara, CA 95054. Phone (408) 988-3500.

Circle No 397

COMPUTERS & PERIPHERALS

TAPE SYSTEM

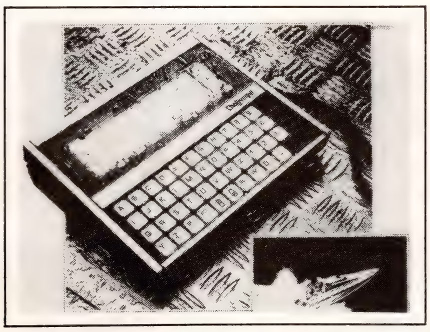
- *40M bytes of backup for IBM PC and compatibles*
- *Supports Novell and 3COM networks*



According to the vendor, the Jumbo 40M-byte tape backup system for the IBM PC, PC/XT, PC/AT, PS/2, and compatible computers can store 10M bytes of data for an IBM PC/AT within five to six minutes. The menu-oriented software is DOS compatible and supports Novell and 3COM networks. File tagging and unattended backup are standard features. An Advanced Reed-Solomon error corrector delivers a bit error rate of 1×10^{-14}. The unit has 5 ICs, and an autocalibration feature adjusts for cartridge-to-cartridge variations so that no further adjustment is required for the life of the drive. It interfaces with the floppy controller and samples the data-transfer rate to automatically set the drive to the fastest available speed. A mounting kit adapts the drive to the PS/2 internal 3½-in. drive slot. $300.

Colorado Memory Systems Inc, 800 S Taft Ave, Loveland, CO 80537. Phone (303) 669-8000. TWX 910-930-9021.

Circle No 400



HANDHELD COMPUTER

- *Operates over a −25 to +55°C range*
- *Runs the CPM operating system and has two RS-232C ports*

Configured for ruggedized applications, the Microscribe Challenger handheld computer is waterproof and operates over a −25 to +55°C range. It comes with two RS-232C ports, 128k bytes (expandable to 320k bytes) of memory, an 8-line×40-character LCD display, and a 48-key membrane-type keyboard. Nickel cadmium batteries act as the device's power supply and typically provide 40 hours of life. The firmware includes a CPM operating system and an extended basic interpreter. The optional software, supplied on a 360k-byte IBM disk, allows file transfers between the unit and an IBM PC or a compatible computer. Also available is optional barcode software for data collection. You can buy the unit with a built-in CCITT V.21 modem that runs at 300 baud. The computer measures 8.4×6.4×1.5 in. and weighs 3.9 lbs. From $2280. Delivery, six to eight weeks.

Amlan Inc, 97 Thornwood Rd, Stamford, CT 06903. Phone (203) 322-1913. TLX 643647.

Circle No 401

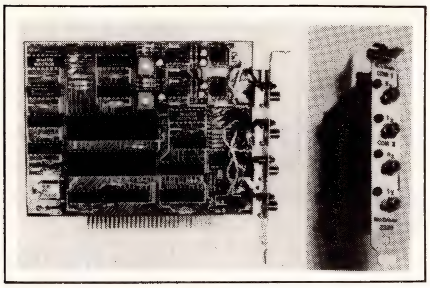
AC WATTMETER

- *Measures 0.5 to 20A in 120 through 230V ac systems*
- *Operates with 50 to 400 Hz single- and 3-phase systems*

The DP-960 AC wattmeter measures power in 120 through 230V ac systems; it measures current from 0.5 to 20A with an accuracy of 0.5%, giving it a power-measurement range of 50 to 4000W. Hall-effect transducers monitor single- and 3-phase systems operating from 50 to 400 Hz. You can use a built-in relay to switch local or visual alarms, or as a thermostatic controller. The unit has either an RS-232C or RS-422 port for data transmission. It is compatible with software packages supporting serial-input data such as LabTech Notebook. It comes in a black metal case with 4½-digit red LED displays that are 0.56 in. high. $450.

Acculex Inc, 440 Myles Standish Blvd, Taunton, MA 02780. Phone (617) 880-3660. TLX 503989.

Circle No 402



BIT DRIVERS

- *Asynchronous optical links for the IBM PC*
- *Optical links can be as long as 15,000 ft*

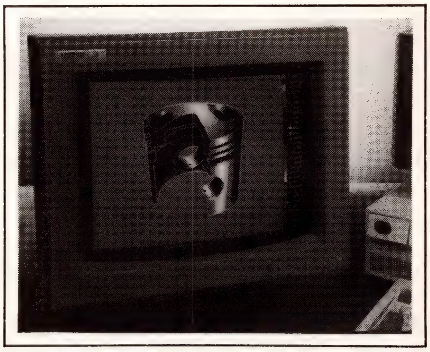
The Models 2320 I and II bit drivers are board products for the IBM PC, PC/XT, PC/AT, or compatible computers. Model 2320 I offers one full-duplex RS-232C channel, and Model 2320 II offers two RS-232C channels of asynchronous communications over fiber-optic links. The optical links are as long as 10,000 ft with an option of 15,000 ft. Each port can operate independently with data rates as high as 19.2k bps. The primary channel operates as a COM I port addressed at 3F8. The alternate channel operates as a COM II port addressed at 2F8. Two SMA connectors or 1 AMP Optimate fiber-optic receptacle/channel serve as transmission line interfaces. Optical power into a 50-μm-core optical fiber is 2 μW at a wavelength of 880 nm. The board comes with diagnostic software. Model 2320 I, $490; Model 2320 II, $690.

SI Tech, Box 609, Geneva, IL 60134. Phone (312) 232-8640.

Circle No 403

DISPLAY SYSTEMS

- *Display 16 colors from a pallette of 4096 colors*
- *Interface to the IBM PC/AT and PS/2 computers*



Xcellerator 1600 Series color graphics-display systems provide a display resolution of 1600×1200 pixels and are compatible with both IBM PC/AT and IBM PS/2 computer architectures. They feature a 20-in. diagonal display and incorporate the Texas Instrument 34010 32-bit graphics system processor to achieve continuous vector-drawing speeds in excess of 80,000 vectors/sec, and 8×16-pixel character generation at 25,000 cps. You can operate the display system in two modes. The first mode displays 16 colors from a palette of 4096 colors, at a display resolution of 1600×1200

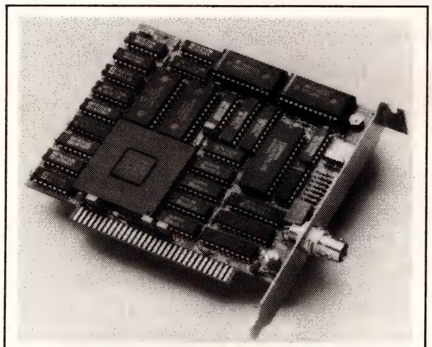
pixels. This mode utilizes a noninterlaced scan with a 60-Hz frame rate, a 75-kHz horizontal line rate, and a pixel clock frequency of 160 MHz. The second mode emulates the vendor's original Xcellerator display system, displaying 256 colors from a palette of 16.7M colors, at a display resolution of 1024×768 pixels. In its standard configuration, the unit includes 1M byte of display-list RAM, but you can upgrade this to as much as 8M bytes. It connects to an IBM PC or compatible via a 2m cable and either a PC/AT-bus- or a Micro-bus-compatible interface card. Around £5500.

Cambridge Computer Graphics Ltd, Graphics House, Convent Dr, Waterbeach, Cambridge CB5 9QT, UK. Phone (0223) 863311. TLX 817274.

Circle No 404

Cambridge Computer Graphics Ltd (USA), 6114 Lasalle, Suite 435, Oakland, CA 94611. Phone (415) 530-4148.

Circle No 405



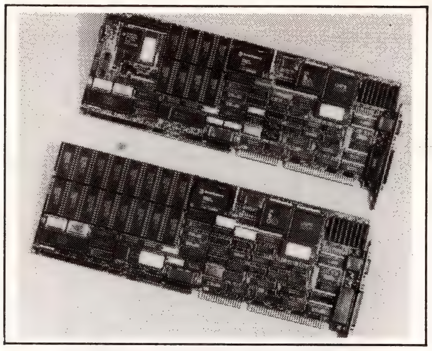
ADAPTER CARD

- *Communicates with an IBM 3274 or 3174*
- *Uses any one of three IBM SNA protocols*

The AdaptCoax is a multiprotocol communications adapter board for the IBM PC, PC/XT, PC/AT, and compatible computers. It provides a PC-to-host communications link to an IBM 3274 or 3174 cluster controller attached with coaxial cable, using any one of three IBM System Network Architecture (SNA) protocols: 3270; Logical Unit 6.2 Advanced Program-to-Program Communications (LU6.2/APPC); and 3770 Remote Job Entry (3770/RJE). You can switch between protocols by running different communications software. The unit takes advantage of the distributed-function terminal (DFT) feature of the 3274/3174 computers to achieve multiprotocol communications. The software runs under PC-DOS 2.0 or later versions, and requires at least 256k bytes of memory. Board, $595; software products, from $285 to $785.

Network Software Associates Inc, 22982 Mill Creek, Laguna Hills, CA 92653. Phone (714) 768-4013.

Circle No 406



PC-BOARD SERIES

- *Integrate multiple functions on a single board*
- *Each board plugs into an IBM PC/AT connector*

The MC Series boards are designed for industrial applications for IBM PC/AT- and 80386-compatible computers. They integrate video and disk controllers, CMOS static RAM, EPROM storage, and parallel and serial communications ports on a single board. The video outputs conform to IBM CGA- and EGA-compatible and Hercules monochrome-compatible standards. You can currently choose between two boards in the series: The MC-01 contains a SCSI hard-disk controller and 256k bytes of CMOS static RAM or 512k bytes of EPROM; the MC-02 contains 512k bytes of CMOS static RAM or 1M byte of EPROM. Both boards feature lithium batteries for backup in case of power failure. MC-01, from $650 (100).

Texas Microsystems Inc, 10618 Rockley Rd, Houston, TX 77099. Phone (713) 933-8050.

Circle No 407

DISPLAY SYSTEM

- *Combines IBM PC/AT computer with 19-in. monitor*
- *Monitor operates with scan frequencies of 21 kHz to 33 kHz*

The Cebra 286 display system, which combines an IBM PC/AT or a compatible computer with a 19-in. Vari-Sync color monitor, can function as a stand-alone terminal or as a remote information display. The standard configuration contains an 80286 μP, running at 8 MHz or 10 MHz; it also includes 1M byte of RAM, two serial ports, one parallel port, a real-time clock, and an IBM PC/AT-style keyboard. The vendor's EGA board, which is really two EGA cards, permits screen

overlays; it provides resolutions of 640×480 pixels. The Vari-Sync monitor operates with scan frequencies of 21 kHz to 33 kHz. With a 13-in. monitor, $3600; with a 19-in. monitor, $4000.

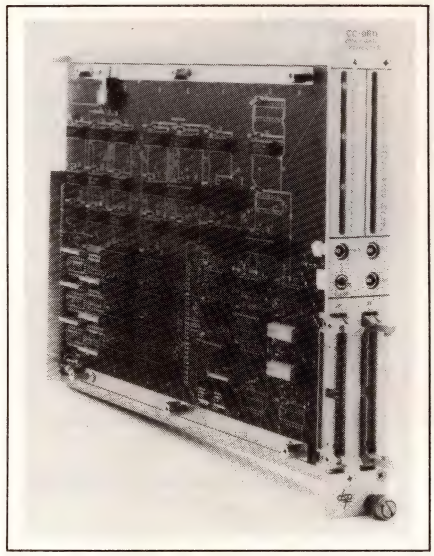
Colorgraphic Communications Corp, Box 80448, Atlanta, GA 30366. Phone (404) 455-3921.

Circle No 408

CAMAC BOARD

- *Links the IEEE-583 bus to DEC computers*
- *Crates can be located as far as 50 ft from the host*

The CC-DR11 interface board for the CAMAC IEEE-583 instrument bus handles data transfers to DEC computers. It can transfer parallel



data at rates as high as 1M words/sec. Based on the DEC DR11 standard, the board provides an interface to the DEC Q Bus, Unibus, and Bibus host computers, using DRV-11WA, DR-11W, and DR32B-W DMA interface boards, respectively. A built-in data display simplifies system maintenance and program development. The board can handle both programmed-I/O and DMA mode transfers. Each DR11 interface can address as many as eight crates located as far as 50 ft from the host. The board can also provide a DR11-type interface for other host computers. A CAMVMS software-driver package supports the board when it's using the VMS operating system. $2500. Delivery, six weeks ARO.

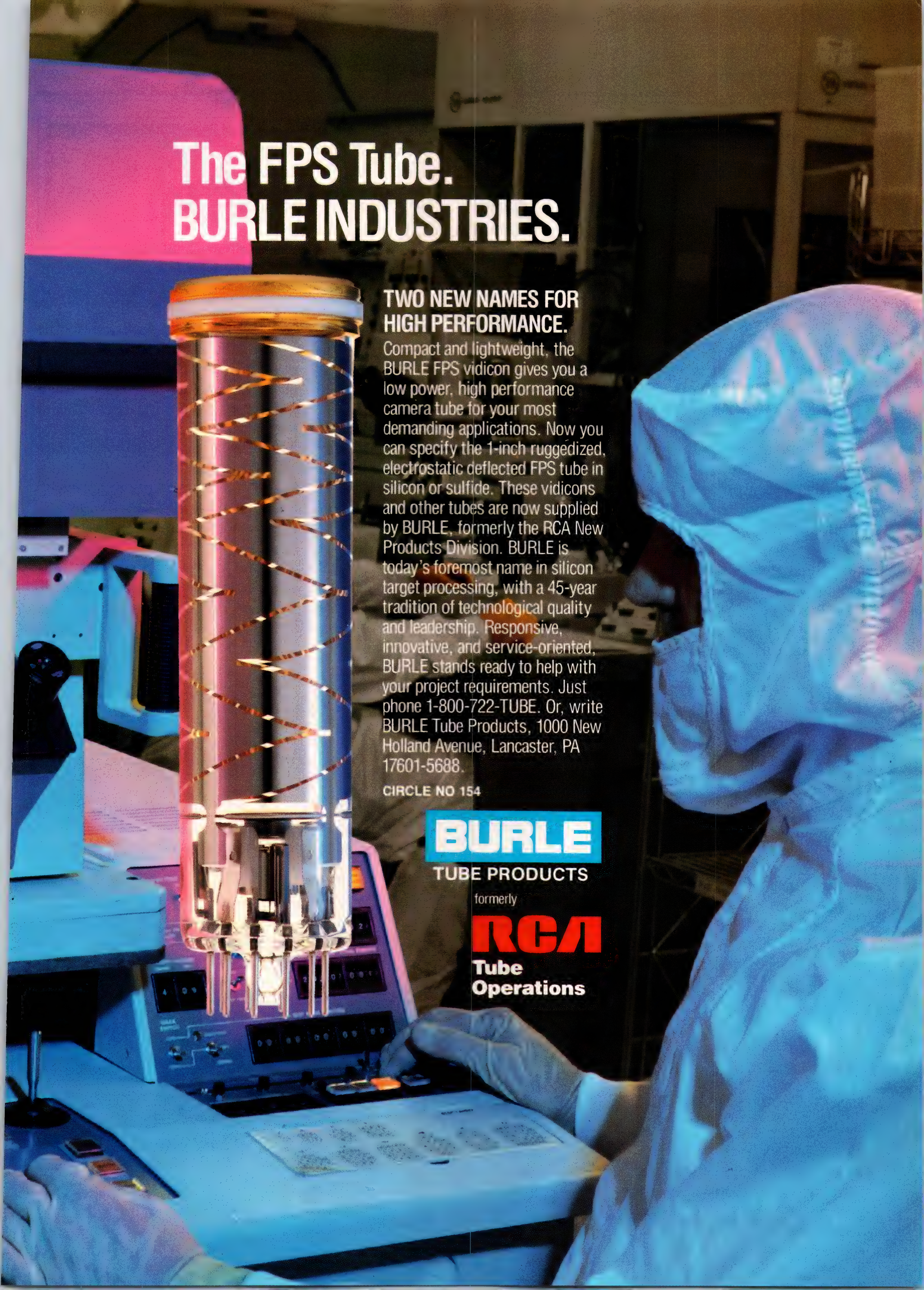
DSP Technology Inc, 48500 Kato Rd, Fremont, CA 94538. Phone (415) 657-7555. TLX 283608.

Circle No 409

MULTIFUNCTION CARD

- *Provides VME Bus systems with I/O and memory functions*
- *Housed on a single Eurocard*

The VMFB single-Eurocard VME Bus board provides you with various system and I/O functions. The board includes a 68562 IC to provide two serial I/O ports and a 16-bit timer counter; a 68230 IC that provides 16 parallel I/O lines and a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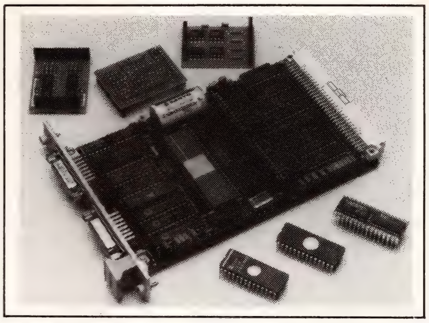


24-bit timer; and an ICM7170 battery-backed, real-time clock/calendar. The board also has space for 64k or 256k bytes of battery-backed static RAM or ROM, and it includes system wake-up and sleep functions, and a hardware watchdog timer. Its VME Bus slave interface includes five programmable VME Bus interrupt levels, short and standard address-mode access to the board's I/O facilities, and standard address-mode access to its memory. DM 890 (OEM qty).

Pep Modular Computers GmbH, Am Klosterwald 4, 8950 Kaufbeuren, West Germany. Phone (08341) 81001. TLX 541233.

Circle No 410

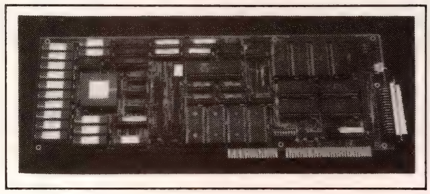
Pep Modular Computers Inc, Carnegie Office Park, 600 N Bell Ave, Pittsburgh, PA 15106. Phone (412) 279-6661. TLX 6711521.

Circle No 411

ADD-IN PROCESSOR

- *Provides IBM PC/AT with a dedicated DSP processor*
- *Suits real-time DSP and process control applications*

The DSPB 2100 add-in board for IBM PC/AT and compatible computers provides the processing power of an Analog Devices' ADSP-2100 digital signal processor. It has a 16k×24-bit RAM for application programs, a 16k×24-bit data RAM in the program-memory space, and a 16k×16-bit data RAM in the data-memory space. All the RAMs are



accessible without wait states, allowing the board to achieve a continuous throughput of 8 MIPS. You can also install as much as 8k×24 bits of boot EPROM. In addition to the 16-bit, 2.66M-byte/sec interface to the computer's IBM PC/AT bus, the board has two auxiliary 16-bit input ports and two auxiliary output ports to transfer data to or from the board. All the ports incorporate 1k×16-bit FIFO buffers that allow them to sustain a continuous data transfer rate of 8M bytes/sec or burst-mode I/O transfers at rates as high as 70M bytes/sec. The board also has two RS-232C I/O ports. The optional piggyback boards provide A/D and D/A converters for analog inputs and outputs. The support

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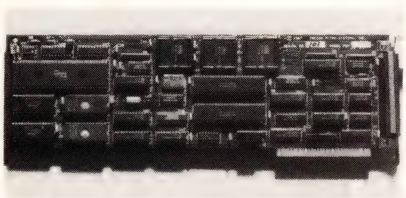
material includes software for program development and simulation, and for communication between the DSPB 2100 and the IBM PC/AT. DM 9950.

CMS GmbH, Einsteinstrasse 61-63, 7505 Ettlingen, West Germany. Phone (07243) 31001.

Circle No 412



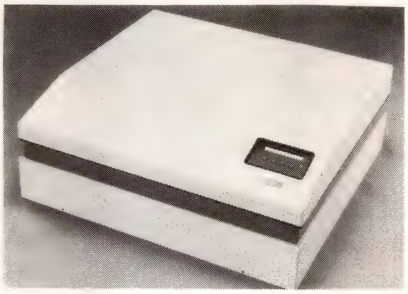
MOTION CONTROLLER

- *Can control as many as 6 axes for IBM PC, PC/XT, or PC/AT*
- *Controls motor drives that accept digital commands*

Occupying a single slot in an IBM PC, PC/XT, PC/AT, or a compatible computer, the PCX intelligent motion controller controls stepping, linear, or servo motors that accept digital step and direction commands. It delivers pulse rates as high as 524,000 steps/sec and has a position range of 134M pulses for each axis that is being controlled; therefore, it can control high-resolution motor drives having as many as 50,000 steps/revolution. Different configurations control 2, 4, or 6 axes independently or synchronized for coordinated moves. The board has independent inputs for limit-switch commands and home-sensor signals for each axis. The data and commands are put into ASCII command strings. Each axis has a separate queue that lets the host download a command sequence and proceed with other tasks while the board manages the motion process. 2-axes version, $995.

Oregon Micro Systems Inc, 14273 NW Science Park Dr, Portland, OR 97229. Phone (503) 644-4999.

Circle No 413



PHOTOPLOTTER

- *Accuracy of 0.025 mm for 300×400-mm plot area*
- *Suitable for desktop use*

Suitable for use with PC-based pc-board CAD systems, the P15 horizontal flatbed photoplotter is a desktop plotter with a plotting surface of 300×400 mm. Its positional accuracy and repeatability on the plotting surface is ±0.025 mm. The plotter has a simple optical head that provides 32 fixed symbols, each driven by a separate LED light source. The head can expose a maximum of 500 pads/minute and draw at 25 mm/sec. Interfaced to a host computer via a 300- to 9.6k-baud RS-232C interface, the plotter accepts RS-274 format (Gerber) graphics codes. You can operate the plotter in normal lighting conditions except when you insert or remove the photographic film. The P15 measures 730×675×265 mm and weighs appproximately 70 kg. It operates from 110 to 220V, 50 to 60 Hz, single-phase ac line supplies. Sw Fr 35,000.

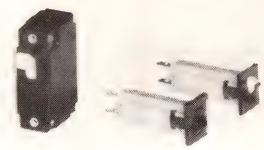
EIE Electronic Industrial Equipment SA, 15 rue Eugene-Marziano, 1211 Geneva 24, Switzerland. Phone (022) 423260. TLX 429484.

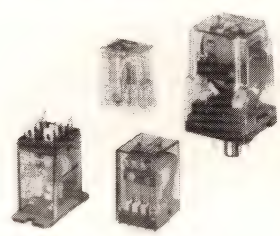
Circle No 414

I/O CONTROLLER

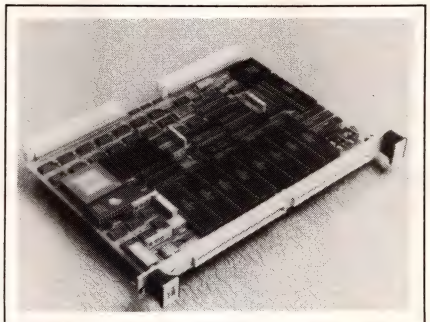
- *Uses a 68020 μP to control 16 serial ports*
- *Device drivers support Unix and OS-9 operating systems*

The PME SIO-4 is an intelligent serial communications controller for





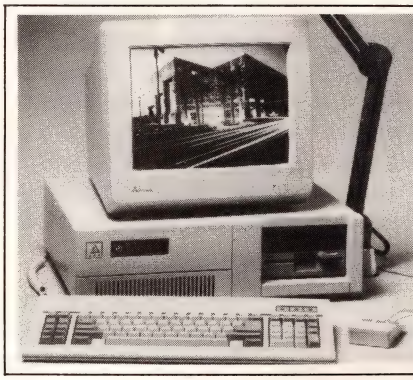
the VME Bus. A 16-MHz onboard 68020 μP offloads I/O processing overhead from the main CPU. The board contains 1M-byte min of RAM, which is dual ported to the 68020 and the VME Bus. The unit controls 16 RS-232C asynchronous channels at baud rates as high as 38.4k baud. You can configure each port for connection to either a ter-



minal or modem. Two additional channels handle synchronous or asynchronous transfers. The unit's self-test and boot facilities reside in 128k bytes of EPROM. The Lincs firmware supplied with the board handles character buffering and interrupt processing for the 16 asynchronous channels. It also manages the queues, input block asssembly, and flow control. Device drivers are available for the Unix and OS-9 operating systems. $2695.

Plessey Microsystems, 1 Blue Hill Plaza, Pearl River, NY 10965. Phone (800) 368-2738; in NY, (914) 735-4661.

Circle No 415



VIDEO SYSTEM

- *Sends color video pictures over telephone lines*
- *IBM PC-family computer board does video compression*

The PC Image Phone, a system color still-frame video phone, stores and retrieves color video pictures and transmits them over telephone lines. You can use the device with an IBM PC, PC/XT, PC/AT, or compatible computers. A compression algorithm lets you transmit color pictures in 5 to 15 sec, when you use a 9600-baud mode. The system includes a 40M-byte hard disk that can store 2000 color stills with TV resolution. The system also includes a PC/AT-compatible computer with a keyboard, a dual-purpose RGB/NTSC monitor, a video-compression and frame-capture board, a color camera, custom operating software,

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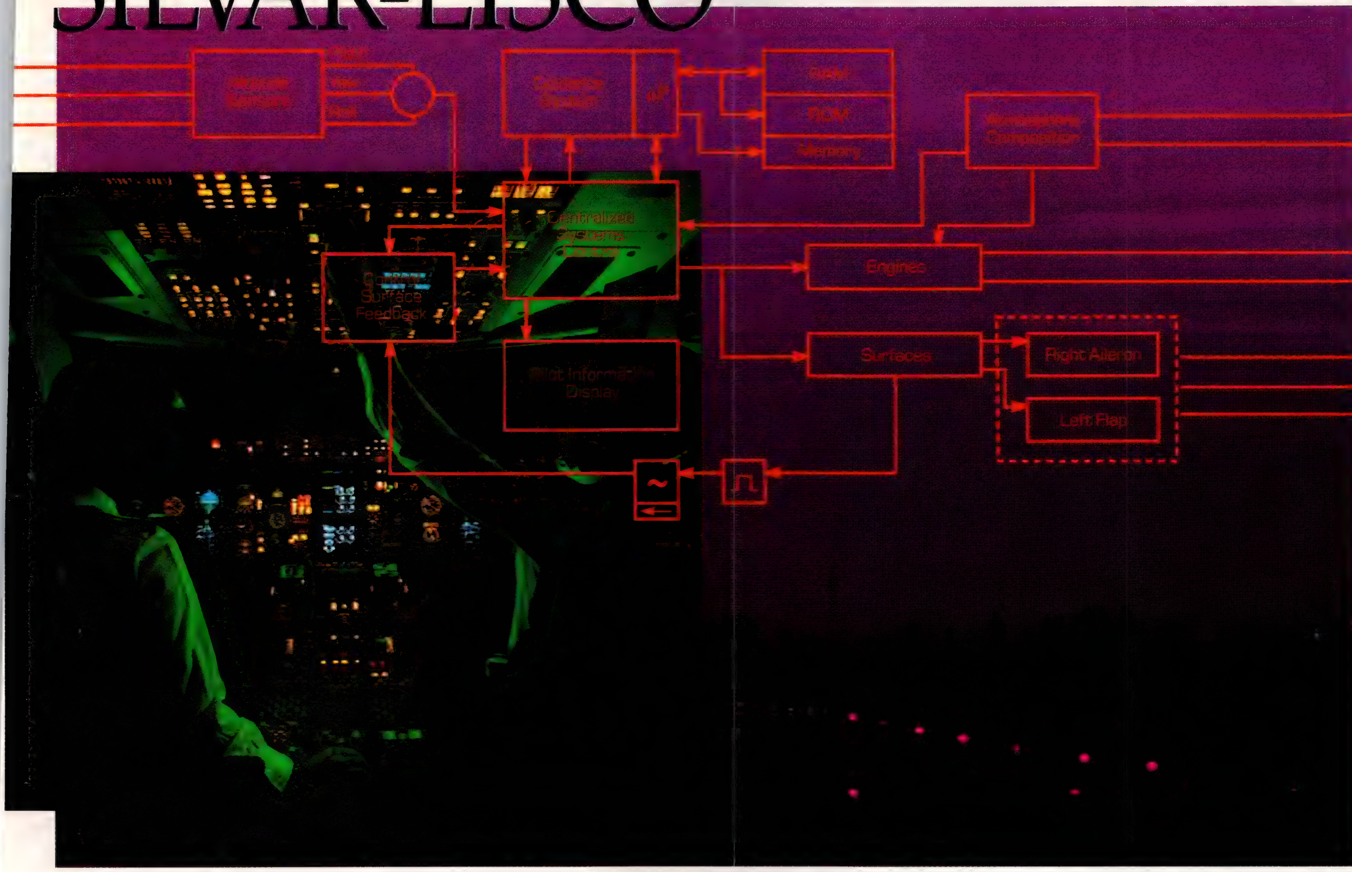

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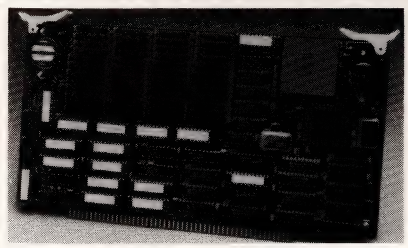
CIRCLE NO 162

COMPUTERS & PERIPHERALS

a 9600-baud modem, and a mouse. A video printer, a write once/read many storage unit, a speaker phone, and a copy stand are optional. Complete system, $12,995; video compression board, $1995.

StarSignal Inc, 1210 S Bascom Ave, Suite 221, San Jose, CA 95128. Phone (408) 294-9604.

Circle No 416



SATELLITE BOARD

- *For the S-100 Bus uses the 80386 μP*
- *You can install seven satellite boards in a system*

The MI386S, a 80386-based satellite board for the S-100 Bus, runs at 16 MHz. You can install as many as seven boards in a system, permitting multiple use. Each board communicates with the host only. The satellite board has 1M byte of 32-bit-wide dynamic RAM. The RAM is dual ported to the 80386 and host processor and has a 100-nsec access time. Compatible host CPUs include the vendor's M1286 and Compupro's 8085/8088 and 80286. The software is compatible with Concurrent DOS, including CDOS 3.2, 4.1, and 5.0. The software has a default feature that is set to the host or to the satellite board running the fewest tasks. You can set a program file to run on a selected processor by modifying a file header. $2667.

Macrotech International Corp, 21018 Osborne St, Building 5, Canoga Park, CA 91304. Phone (818) 700-1501. TWX 910-997-0653.

Circle No 417

On April 5th, Intel made a major announcement about advanced 32-bit embedded control technology.

On April 12th, we'll explain it.

Intel unveiled three advanced embedded control technologies, two 32-bit embedded processors, and a radically new memory product line on April 5th.

On April 12th, seminars begin worldwide to show how to design significantly more powerful 32-bit systems that provide unparalleled price performance. The fully supported 80376 and 80960 families of embedded processors, and the breakthrough flash memory technology will be discussed in detail.

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Michigan	Detroit	4/25/88
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New Jersey	Kenilworth	5/13/88
New York	Binghamton	5/11/88
	Long Island	4/13/88
	Rochester	5/10/88
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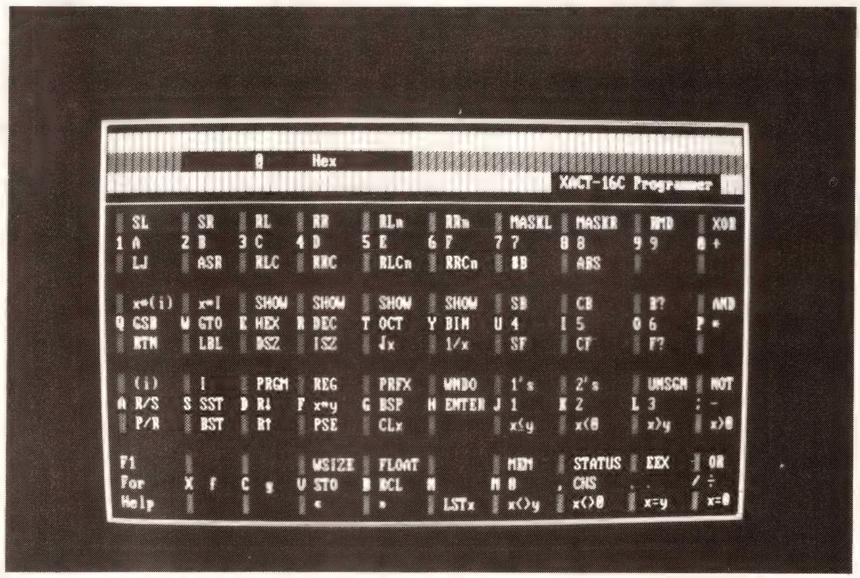
	Ottawa, Ontario	5/25/88
	Toronto	5/20/88
	Vancouver, BC	5/6/88

CIRCLE NO 214

CAE & SOFTWARE DEVELOPMENT TOOLS

CALCULATOR SOFTWARE

- *Pop-up calculator simulates HP-16C programmers' tool*
- *Lets you print or save simulated HP-16C program tapes*



XACT-16C is a RAM-resident, pop-up calculator that you can call from within other programs and that simulates the HP-16C handheld programmable calculator. It runs on the IBM PC, PS/2, and compatibles. The calculator features decimal, octal, hex, binary, and floating-point modes with any word size from 2 to 64 bits. It provides advanced algebraic, logical, base-conversion, and bit-manipulation functions not found in other calculators. The calculator is fully programmable and generates a simulated paper tape that you can "stamp" with messages, print, or save to a disk file. The calculator also provides on-line help in the form of menus and a table of ASCII codes. $49.95.

CalcTech Inc, 13629 Bellevue-Redmond Rd, Suite 202, Bellevue, WA 98005. Phone (206) 643-1682.

Circle No 420

GRAPHICS TOOL KIT

- *Helps you program graphics for PCs that use the TI34010 chip*
- *Allows calls from Pascal and C programs*

The RGDI Developer's Kit consists of the vendor's advanced graphics controller, which is based on the 32-bit TI34010 graphics coprocessor chip; a programmer's technical reference manual; a TI34010 user's guide; and development software and utilities. You can program the TI34010 chip in one of three ways: through the use of high-level drawing primitives that allow you to call them from applications written in C or Pascal, by building new primitives written in the TI34010 assembly language, and by writing custom programs entirely in the TI34010 assembly language. For this purpose, the tool kit includes an assembler, a linker, a simulator, a debugger, and utility programs. The graphics programs that you develop will run on an IBM PC or compatible equipped with the vendor's Rendition I graphics controller board. If you need EGA compatibility, the vendor can supply an optional Rendition EGA (REGA) plug-in module. Developer's Kit, $695; REGA, $169.

Renaissance GRX Inc, 2265 116th Ave NE, Bellevue, WA 98004. Phone (206) 454-8086.

Circle No 421

C COMPILER FOR MAC

- *Provides source-level compatibility with MPW*
- *Works with 68020 and 68881 math coprocessor*

Release 3.6 of Aztec C makes the compiler fully compatible with the Macintosh II and with all other Apple machines and interfaces, including Apple's Macintosh Programmer's Workshop (MPW). The compiler allows you to make full use of the 68020 CPU and 68881 math coprocessor; the package includes a library of floating-point math routines for the 68881, as well as a library of IEEE floating-point routines. Enhancements bring the compiler into closer conformity with the ANSI draft standard for C by allowing you to use new extensions such as bit fields, structure passing, and *enum,* which lets you define new data types. Version 3.6 allows you to create code segments of virtually unlimited size. The package works with third-part debuggers such as MACsbug, MACnosy, and TMON, and it includes a profiler that identifies performance bottlnecks. You can obtain the package in three upgradeable configurations: C' Prime, $75; Professional, $199; and Developer, $299.

Manx Software Systems Inc, 1 Industrial Way, Eatontown, NJ 07724. Phone (201) 542-2121.

Circle No 422

CAE SYSTEM

- *Provides multilayer routing and ECO processing option*
- *Supports SMT with blind and buried vias*

The Master Designer 386 CAD/CAE system is a software package that runs on 80386-based computers as well as on 80286-based PCs and compatible computers. The system handles board designs two to three times as large as does its predecessor, the PCB-3, and it runs faster as well. The system includes a multilayer routing feature that yields a higher completion rate than does the PCB-3. According to the vendor, this feature reduces the number of vias by 30 to 50% and also reduces the number of unconnected subnets. An ECO (engineering change order) processing feature provides both forward annotation of logic changes and history-independent back annotation. The design database can accommodate data on as many as 500 equivalent ICs, 32,000 pins, and 2500 nets. The system lets you use surface-mount technology with blind and buried vias. Menus with explicit prompts and messages guide you through the logical progression of tasks in the design process. Other features include support for Novell/3Com Ethernet networking, a network-comparison utility, and extensive checking of your design against your engineering design rules. The system works with 60 different printers and plotters. $16,980.

Personal CAD Systems Inc, 1290 Parkmoor Ave, San Jose, CA 95126. Phone (408) 971-1300. TLX 3717199.

Circle No 423

LINKER FOR 80386

- *Links object modules intended for ROM-resident software*
- *Accepts object files from many 16- and 32-bit compilers*

The LinkLoc software package combined linker and locator utility accepts relocatable object modules from assemblers or compilers and produces executable image files that you can download to a target system or to a PROM programmer. Switches allow you to control the attributes and sizes of segments, as well as the starting locations of programs. The utility automatically constructs LDTs (local descriptor tables) and GDTs (global descriptor tables), which are required by programs that run in protected mode on an 80286 or 80386. The utility can also produce a symbol table for use by a symbolic debugger or by an in-circuit emulator. The linker accepts object files in OMF-86 format, which is employed by the majority

of 8086 and 80286 compilers; it will also accept files in the vendor's Easy OMF-386 format. Command-line switches let you specify the format of the output file; you can select Intel and Motorola hex formats, Intel Absolute 8086 and Bootloadable OMF-286/386 formats, and MS-DOS .EXE format. IBM PC version, $395; Sun and Apollo versions, from $750; VAX/VMS and VAX/Ultrix versions, from $1495.

Phar Lap Software Inc, 60 Aberdeen Ave, Cambridge, MA 02138. Phone (617) 661-1510.

Circle No 424

OPTICAL DISK SERVER

- *Lets you connect a PC to any of 11 different optical drives*
- *Allows the optical disk to operate like a hard-disk drive*

OS-DOS is an operating-system extension that provides an intelligent optical-drive file system and an appropriate interface to MS-DOS or PC-DOS. OS-DOS 3.0 is for single-user systems; OS-DOS 4.0 allows the optical drive to act as a file-server on a network. Both versions provide 20-character file names, 65,000 subdirectories, and an unlimited number of files; an individual file can be as large as 2G bytes. OS-DOS is transparent to application programs and allows you to use all MS-DOS system commands; you can truncate, delete, update, or add files on a write-once optical disk. Version 4.0 allows Novell network users to address optical drives transparently as part of the network. The optical drives can be 5¼-, 8-, or 12-in. drives from any of 11 manufacturers. OS-DOS 3.0, 5¼- and 8-in. drives, $937; 12-in. drives, $1875. OS-DOS 4.0 network software, 5¼- and 8-in. drives, $1250; 12-in. drives, $2500.

Optical Storage Solutions Inc, 1130 D Burnett Ave, Concord, CA 94520. Phone (415) 825-3441.

Circle No 425

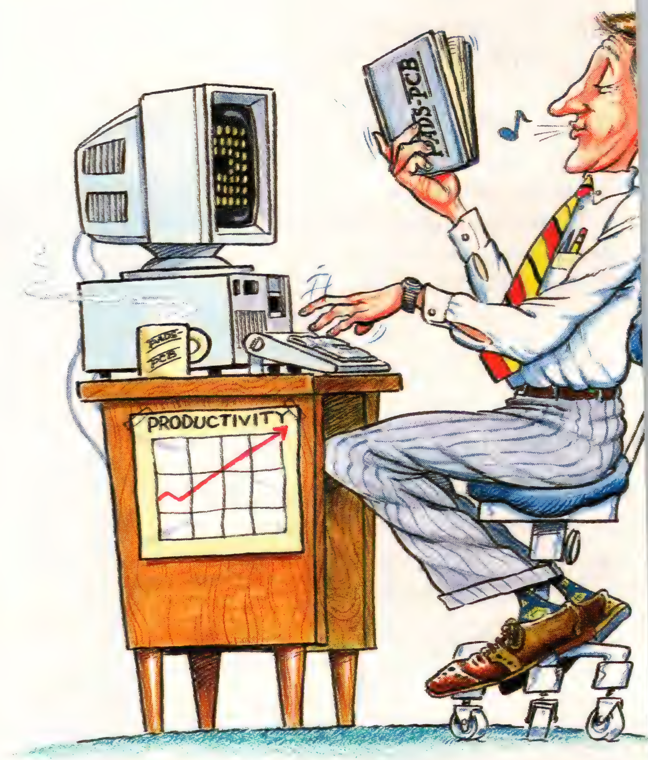
SIMULATOR

- *Lets you simulate nonlinear systems such as servos*
- *Uses HALO graphics system for portability*

The CCAP-SIM "authoring" program accepts input consisting of a model of a feedback control system that you've previously defined with the aid of the vendor's CCAP analysis program. The authoring program then writes source code that, when compiled and linked with other precompiled modules, results in a program that simulates a specific control system. Both the authoring program and the resulting simulation program are interactive and allow you to change parameter

GOODBYE WORKSTATION

HELLO PADS-PCB



It's time to say goodbye

to expensive engineering workstation based CAD systems. Why should management tie up $100,000.00 or more in a workstation when the same (and often better) performance is obtained with PADS-PCB, a PC based CAD system?

PADS-PCB is a high performance printed circuit board design software that offers a degree of functionality a designer could expect only from an expensive engineering workstation.

Powerful auto/interactive features are a part of what makes PADS-PCB the best selling CAD system on the market:

- 1 mil database-32″x32″ board size-30 layers
- Large circuit capabilites: In excess of 400 equivalent 14 pin IC's
- Automatic and interactive component placement aids
- Automatic and interactive track routing
- Automatic design rule checking
- Superior Surface Mounted Device capability
- One, two, and three track capability between IC Pins
- Superb analog design capability
- Inputs from Futurenet, Orcad, Schema, PADS-CAE and others
- 100% routing with PADS-Supe Router, the only rip-up and rerout router on a personal computer

CAD Software asks you to try it Evaluation Package, priced at onl $50.00, so you can see for yoursel how PADS-PCB puts an end to thos workstation blues. Cal our Sales Hotline toda at **(800) 255-7814** in Massachusetts **(617) 486-9521**

119 Russell Street
P.O. Box 1142
Littleton, MA 01460

CAD Software, Inc.

CIRCLE NO 101

CAE & SOFTWARE

values dynamically. To run the program, you need an IBM PC/XT, PC/AT, PS/2, or compatible machine equipped with a math coprocessor and at least 512k bytes of RAM, a hard disk, a parallel printer port, a graphics display adapter, and DOS 2.1 or later. $800.

Lewis Engineering Software, Box 55-BV, Andover, MA 01810. Phone (617) 975-5509.

Circle No 426

AI TOOL

- *Lets you call routines written in Ada and C*
- *Lets you watch areas of memory while debugging*

VAX OPS5 is a tool for developing expert systems and other AI application software. Version 2.2 allows you to call external routines written in VAX C or VAX Ada from within VAX OPS5 programs. Using the interface features, you can integrate expert systems written in VAX OPS5 with other programs written in VAX Basic and VAX Bliss-32. A watch feature allows you to watch specific areas of memory while debugging, so that you have greater control over the debugging process. Further, Version 2.2 will run on any host in the VAX family of computers, starting with the VAXstation 2000. The license fee depends on the host configuration and number of users, starting at $1575 for the VAXstation 2000.

Digital Equipment Corp, 146 Main St, Maynard, MA 01754. Phone (800) 344-4825; in MA, (617) 870-3234.

Circle No 427

FORMAT CONVERTER

- *Translates data to and from digital-signal formats*
- *Lets you acquire binary data from acquisition hardware*

The HEM Universal Translator runs on the IBM PC and compati-

bles and translates data to and from digital-signal formats such as ASCII, floating-point, Intel and Motorola hexadecimal, and binary. The format converter lets you use data-analysis packages such as the vendor's Snap-Calc and Snap-FFT even if your data was acquired with instrumentation that employed a format incompatible with your analysis package's format. The translator will create headers used by the vendor's analysis software and will either strip out or pass on headers created by other acquisition packages. If part of a multiple, HEM-package order, $150; otherwise, $195.

HEM Data Corp, 17025 Crescent Dr, Southfield, MI 48076. Phone (313) 559-5607.

Circle No 428

CADD FOR MAC

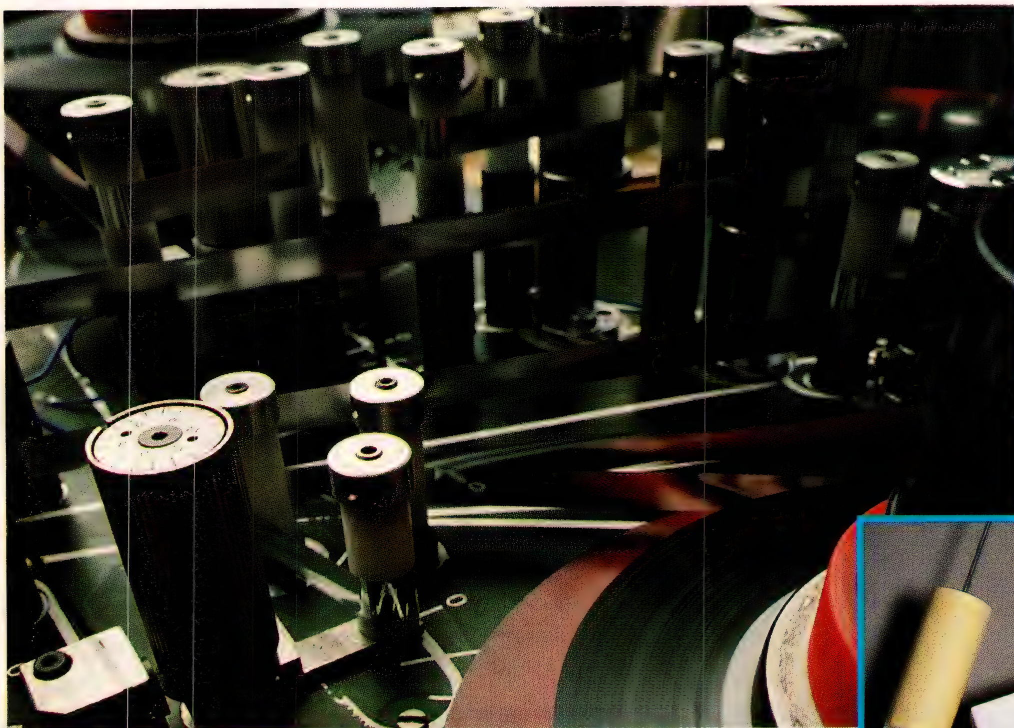
- *Lets you use as many as 256 colors*
- *Lets you group objects together as components*

Generic CADD Level 1 has been redesigned to follow the standard Macintosh interface so that it works like other graphics programs for the Macintosh. You can edit multiple drawings simultaneously in different windows, and you can cut and paste objects between different windows in Level 1 or between Level 1 and other programs that use the standard Pict format. You can use as many as 256 colors, layers, and line types; you can move, copy, erase, or rotate objects that you have drawn on the screen. You can group objects together to form components, and you can save these components for repeated use. This package provides Macintosh users with the same drawing capabilities that earlier versions provided to IBM PC users. $49.95.

Generic Software Inc, 8763 148th Ave NE, Redmond, WA 98052. Phone (206) 885-5307.

Circle No 429

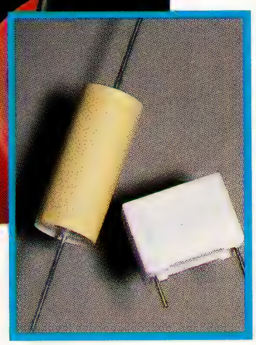
In the World of DC Film Capacitors, Mallory Technology Leads the Way.



Automated high-speed winding operation for DC Film capacitors.

Utilizing the world's finest design technology and high-speed automation equipment, Mallory has become the largest domestic producer of DC Film capacitors.

Mallory offers a wide range of dielectric materials including polyester, polypropylene and polystyrene. And with the additional choice of film-foil or metallized electrodes,



Mallory can provide the most cost-effective match for your application requirements.

With Mallory, the world of DC Film technology and service is at your fingertips.

For more information, contact your nearest distributor or call Mallory today.

Mallory Capacitor. Stronger Than Ever.

Mallory Capacitor Company
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Telephone: (317) 636-5353

MALLORY
ELECTRICAL/ELECTRONIC GROUP

EMHART

ANALOG DEVICES

35ns, 12-Bit
Monolithic D/A Converter

AD568

FEATURES
Ultrahigh Speed: Current Settling to 1LSB in 35ns
12-Bit Integral and Differential Linearity Guaranteed Over Temperature
10.24mA Full-Scale Output Suitable for Video Applications
High Stability Buried Zener Reference on Chip
0.3" "Skinny DIP" Packaging
Variable Threshold Allows TTL and CMOS Interface

AD568 Functional Block Diagram

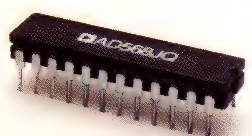
PRODUCT DESCRIPTION
The AD568 is an ultrahigh-speed, 12-bit digital-to-analog converter (DAC) settling to 0.025% in 35ns. The monolithic device is fabricated using Analog Devices' Complementary Bipolar (CB) Process. This is a proprietary process featuring high-speed NPN and PNP devices on the same chip without the use of dielectric isolation or multichip hybrid techniques. The high speed of the AD568 is maintained by keeping impedance levels low enough to minimize the effects of parasitic circuit capacitances.

Laser wafer trimming insures full 12-bit linearity. All grades of the AD568 are guaranteed monotonic over their full operating temperature range. The low linearity error allows the AD568 to be used in high-speed applications requiring real 12-bit performance. There is no longer any compromise between speed and accuracy in those applications that require both.

The DAC consists of 16 current sources configured to deliver a 10.24mA full-scale current output or a 1.024V FS unbuffered voltage output. Multiple matched current sources and thin-film ladder techniques are combined to produce bit weighting. Additionally, a 10.24V FS buffered output may be generated using an onboard 1kΩ span resistor with an external op amp. Bipolar ranges are accomplished by pin strapping.

PRODUCT HIGHLIGHTS
1. The ultrafast settling time of the AD568 allows leading edge performance in waveform generation, graphics display and high-speed A/D conversion applications.
2. Full 12-bit accuracy is provided in a monolithic converter.
3. Pin strapping provides a variety of voltage and current output ranges for application versatility. Tight control of the absolute output current reduces trim requirements in externally scaled applications.
4. Matched on-chip resistors can be used for precision scaling in high-speed A/D conversion circuits.
5. The digital inputs are compatible with TTL and +5V CMOS logic families.
6. Skinny DIP (0.3") packaging minimizes board space requirements and eases layout considerations.

THE SPEED RECORD FOR REAL 12-BIT DAC PERFORMANCE IS SET ON THIS PAGE.



If your high-speed DAC applications are often plagued by a loss of accuracy, we'd like to direct you to our AD568.

With a settling time of only 35ns to ±0.025%, no other monolithic DAC is faster. And the AD568 combines this speed with unmatched ±1/4 LSB integral nonlinearity, as well as guaranteed monotonicity over the entire operating temperature range, for real 12-bit performance.

This unique combination of speed and accuracy allows you to delve into new application areas like high-speed/high-resolution A/D converters, vector graphic displays, and direct digital frequency synthesizers.

For design versatility, the AD568 offers a variety of user-programmable voltage and current outputs. And all this comes in a skinny 0.3" CERDIP package, which conserves board space and allows for auto-insertion.

Now other high-speed monolithics can cost almost twice as much as the AD568, and they still can't deliver the same level of accuracy. And while some hybrids might come close in performance to the AD568, they're also more than double the price.

To find out how the AD568 can help set speed records for your designs, contact the Analog Devices office nearest you.

ANALOG DEVICES

Analog Devices, Inc., One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106; Headquarters: (617) 329-4700; California: (714) 641-9391, (619) 268-4621, (408) 559-2037; Colorado: (303) 590-9952; Maryland: (301) 992-1994; Ohio: (614) 764-8795; Pennsylvania: (215) 643-7790; Texas: (214) 231-5094; Washington: (206) 251-9550; Austria: (222) 885504; Belgium: (3) 237 1672; Denmark: (2) 845800; France: (1) 4687-34-11; Holland: (1620) 81500; Israel: (052) 28995; Italy: (2) 6883831, (2) 6883832, (2) 6883833; Japan: (3) 263-6826; Sweden: (8) 282740; Switzerland: (22) 31 57 60; United Kingdom: (932) 232222; West Germany: (89) 570050

CIRCLE NO 182

CAE FOR WINDOWS

- *Simultaneous access to multiple sheets of a drawing*
- *Checks for violations of design rules*

ICO-CAP is a schematic-capture software package that works with Microsoft's Windows graphics manager and runs on IBM PCs and compatibles. The number of levels in the design hierarchy is limited only by the amount of memory available; you can create very large drawings that extend over many sheets. The package provides simultaneous access to a sheet and a symbol, or to many sheets, or to two different magnifications of the same sheet. The program generates a netlist as a background task during the drawing session—no compilation is necessary. The program performs extensive checking for violation of your design rules and provides on-line help via menus. You can direct output to laser printers, dot-matrix printers, and pen plotters. $695.

IC Options Inc, 970 University Ave, Los Gatos, CA 95030. Phone (408) 395-6680.

Circle No 430

ANALYZER

- *Lets you evaluate thermal aspects of pc-board designs*
- *Accepts positional data from popular CAD/CAE systems*

The Thermal software package runs on IBM PCs and compatibles or on VAX workstations. With the aid of the vendor's RAMCAD interface, the program accepts positional data from popular CAD/CAE systems and lets you evaluate component layout, use of cooling fins, air temperature, airflow rate and direction, and other thermal aspects of your design. Menus and on-line help facilities guide you through the steps involved in acquiring the data and initiating the analysis. The program identifies components that violate the temperature constraints of your specifications; it provides easily interpreted results that will help you predict the thermal characteristics of your board and that you can use to modify your board design and improve your board's reliability and maintainability. You can create additional data for the parts library that comes with the package. IBM PC-based systems, from $3500; VAX-based systems, from $8000.

Systems Effectiveness Associates Inc, 20 Vernon St, Norwood, MA 02062. Phone (617) 762-9252.

Circle No 431

SCIENCE TOOLS

- *Provide C functions that you can call from Turbo C*
- *Offer a set of C functions that you can call from Microsoft C*

The Science and Engineering Tools package consists of a set of C functions for general statistics, multiple regression, curve fitting, integration, FFTs, differential and simultaneous equations, matrix math, complex math, and special functions. The manual describes the form, purpose, and parameters of every function. Sample programs show you how to use the libraries of analysis and graphics functions. The vendor offers these source-code routines in two versions: one that operates with Borland International's Turbo C, and the other with Microsoft C. Both versions are available on either 3.5-in. or 5.25-in. diskettes. $74.95.

Quinn-Curtis, 49 Highland Ave, Needham, MA 02194. Phone (617) 444-7721.

Circle No 432

DSP SOFTWARE

- *Lets you display multiple files simultaneously*
- *Provides basic and advanced DSP functions*

Data Master is a signal-processing software package that runs on IBM

PCs and compatibles. The package combines graphics routines, data-sampling routines, test-data-generation routines, complex-data math routines, DSP (digital signal processing) utilities, and a pipe facility that allows one utility to take its input from the output of another. The package provides a console window for user interaction and a graphics window for the display of data. You can adjust the size and placement of each window and the degree by which it overlaps the other. The DSP utilities include fundamental operations such as forward and inverse FFT routines, convolution, correlation, and filter design and implementation. You can perform multistage transformations by combining the DSP operations with the math functions in data pipes. The package lets you integrate custom routines with the utilities and lets you use a wide variety of data-acquisition hardware and additional analysis software. To run the package, your IBM PC or compatible needs at least 256k bytes of RAM, two floppy-disk drives, and MS-DOS 2.0 or higher; a hard disk and math coprocessor will improve performance. You can use Hercules monochrome graphics and IBM EGA, VGA, or compatible graphics. The package supports most popular dot-matrix printers and the HP LaserJet printer. $115.

Durham Technical Images, Box 72, Durham, NH 03824. Phone (603) 868-7203.

Circle No 433

μP SIMULATORS

- *Let you simulate boards with as many as 10,000 gates*
- *Chip models run on an IBM PC or compatible*

The Susie software simulator runs on the IBM PC and compatibles, and provides behavioral models of 8-bit μPs and microcontrollers. The models are written in 8088 assembly language to ensure acceptable execution speed. The parts library supplied with the package includes all TTL, ECL, and CMOS chips, so that you can simulate pc boards that have as many as 10,000 gates in addition to the processor chip. You can simulate programmable logic devices at the system level by loading their JEDEC fuse maps. The processor models include specialized test patterns for testing basic processor operations. Models of the 8051, Z80, and M68HC11 processor are in development. You can currently obtain a package containing models of an 8-chip processor family that includes the 8035, 8039, 8048, and others. $1495.

Aldec, 3525 Old Conejo Rd, Suite 111, Newbury Park, CA 91320. Phone (805) 499-6867.

Circle No 434

Marconi introduces the only keypad made to give extreme reliability. Under extreme conditions.

Until now, users of keypads in hostile or hazardous environments have had to accept poor tactile response and slower operating time as the price for protection. With the introduction of Marconi's SF62000 keypad line, those days are over.

Marconi's SF62000 keypads are of revolutionary non-mechanical construction. A molded rubber mat is secured around a rigid circuit plate providing an environmental seal* that offers total protection against dirt, dust, heat, cold, liquids, gases and other hazards of modern industrial, military and medical usage. The new construction accepts data as fast as the operator can hit the keys, with positive tactile "snap action" confirming contact even when the keys are not struck precisely.

The SF62000 line is available in 4, 12, 16 key and QWERTY formats in a variety of mat colors and keytop legends. For complete information, including the availability of samples, write or call today.

*Exceeds BS 5490 (Class IP67) requirements.

See us at EDS Show April 26-28, Booth No. 631

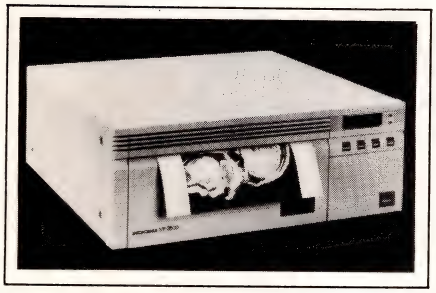
Marconi

Electronics Devices, Inc.
MICROSYSTEMS DIVISION
45 Davids Drive, Hauppauge, NY 11788
516 231-7710, FAX: 516 231-7923

CIRCLE NO 186

NEW PRODUCTS

TEST & MEASUREMENT INSTRUMENTS



VIDEO PRINTER

- *Works with terminals and TV cameras*
- *Reproduces 300 dots/in. with 64-tone gray scale*

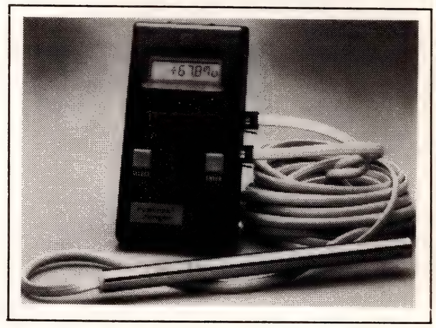
The VP-3500 video printer provides 1280×1250 pixels of resolution at 300 dots/in. with a 64-tone gray scale on 8.5-in.-wide, thermal-print paper. It connects to computer CRT terminals, TV cameras, and image-processing systems. The unit lets you select white-on-black or black-on-white printing and includes a frame buffer for storing images to be printed. Its front panel sports a 32-character LCD display. $6700.

Seikosha America Inc, 1111 MacArthur Blvd, Mahwah, NJ 07430. Phone (800) 422-7768; in NJ, (201) 529-4655.

Circle No 440

TEMP/RH RECORDER

- *Records temperature and humidity for 100 days*
- *Transfers data to computer via RS-232C port*



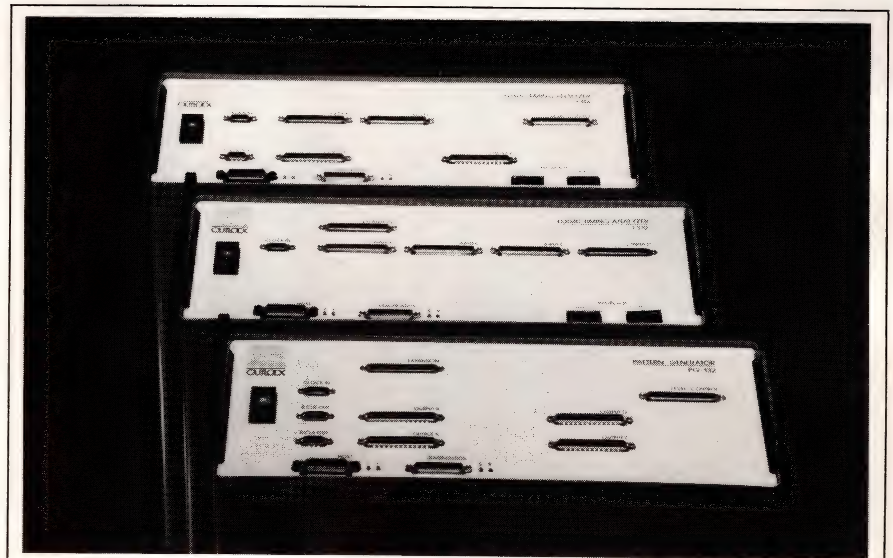
The Ranger data logger, in combination with the temperature and relative humidity (RH) probe, records temperature and humidity for periods as long as 100 days. The unit captures the data without using paper; after a recording session, you can use the unit's RS-232C port to transfer the captured data to an IBM PC or compatible computer for analysis and print out. The system performs humidity measurement at an error rate of <±2%/year; it offers <2% nonlinearity, and <1% hysteresis. The probe suffers no permanent damage from complete immersion in water and resists damage from sulfur-compound pollution. $844. Delivery, four to six weeks ARO.

Rustrak Instruments, Rte 2 and Middle Rd, East Greenwich, RI 02818. Phone (800) 332-3202; in RI, (401) 884-6800.

Circle No 441

TIMING INSTRUMENTS

- *Perform timing analysis at 500 MHz*
- *Generate 32-bit-wide patterns at 250 MHz*



The T-132 logic timing analyzer provides a maximum of 32 channels. Depending on the number of channels installed, it makes timing measurements at either 250 or 500 MHz. The PG-132 is a 32-channel, 250-MHz pattern generator. The T-116 provides 16 channels of 500-MHz timing analysis and 250-MHz pattern generation. The configuration of the timing analyzers determines their maximum memory depth; they can have 4 to 16k words of memory. The pattern generators offer 4k-word memory depth, but they can generate repetitive patterns of infinite length. An equivalent-time sampling option endows the T-132 with 100-psec resolution for measurements on repetitive waveforms. Another T-132 option lets it capture setup and hold-time violations, a capability that is standard on the T-116. You can position the capture window from 4 nsec before to 16 nsec after an external clock's active edge, and you can make the window width as long as 1.5 nsec, in 200-psec increments. $14,750 to $19,750.

Outlook Technology Inc, 200 E Hacienda Ave, Campbell, CA 95008. Phone (408) 374-2990. TLX 350479.

Circle No 442

SHARP FLAT PANEL DISPLAY

Thin is In.

As any designer will attest, the latest rage in the electronics industry are liquid crystal and electro-luminescent flat panel displays. The reason for their popularity is clear — thin displays mean sleeker, more efficient designs.

Sharp is the recognized leader in LCD and EL flat panel displays. With over 30 years experience in building the world's clearest, most reliable displays, Sharp is sure to make an LCD to fit your needs.

Of course, the most popular place to order your Sharp displays is Marshall Industries. In fact, Marshall is the only national distributor of Sharp LCDs. But that's the kind of privilege you expect when you have over 30 years experience serving the electronics industry.

When you need a clear display that fits just right, remember the leader in flat panel displays. Sharp. And remember the best place to find them. Marshall.

Because Marshall knows you can never be too sharp or too thin.

Marshall

(*Authorized Locations)
AL Huntsville (205) 881-9235*
AZ Phoenix (602) 496-0290*
Tucson (602) 790-5687*
CA Irvine (714) 859-5050*
Los Angeles (818) 407-4100*
Sacramento (916) 635-9700*
San Diego (619) 578-9600*
San Francisco (408) 942-4600*
CO Denver (303) 451-8383*
CT Connecticut (203) 265-3822*
FL Ft. Lauderdale (305) 977-4880*
Orlando (305) 767-8585*
Tampa (813) 576-1399*
GA Atlanta (404) 923-5750*
IL Chicago (312) 490-0155*
IN Indianapolis (317) 297-0483*
KS Kansas City (913) 492-3121*
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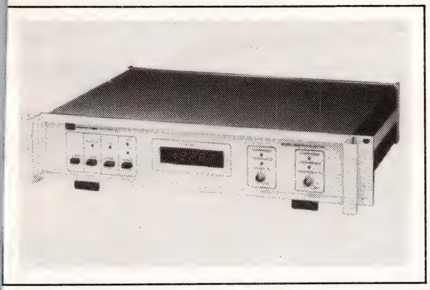


DIGITAL PHASE METER

- *Handles 5 Hz to 500 kHz*
- *Accepts amplitudes from 10 mV to 350V*

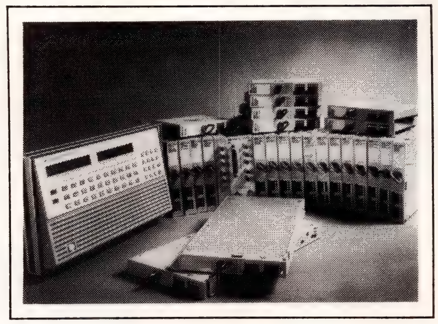
The Model 6000 autoranging digital phase meter includes an IEEE-488 interface. It accepts signals whose amplitudes range from 10 mV to 350V at frequencies from 5 Hz to 500 kHz, with sine, square, or triangular waveforms. The meter's 5-digit LED display can resolve phase changes as small as 0.01° from −180° to +360°. The meter's accuracy is guaranteed to be better than ±0.05° for sine or square waves. The rear panel has a connector from which you can obtain an analog voltage that's proportional to the measured quantity (the calibration factor is −10 mV/°). The rack-mountable unit measures 19×3.5×14 in. $3295.

Clarke-Hess Communication Research Corp, 220 W 19th St, New York, NY 10011. Phone (212) 255-2940.

Circle No 443

ACQUISITION MODULES

- *Compatible with HP 3852A control unit*
- *Output data at 800k points/sec; input at 100k points/sec*



The HP 44700 Series of I/O modules for the HP 3852A data-acquisition and control mainframe now includes four additional modules. One is a dual-channel D/A converter with 16-bit resolution and 14-bit monotonicity. This converter can accept new data at a rate of 800k points/sec. Another module is a 4-channel multiplexer which, for each channel, contains an amplifier whose gain is programmable to values of 1, 10, and 100; a 4-pole, lowpass Bessel filter with 10-kHz cutoff frequency; a track-and-hold circuit; and a peak detector. The other two modules are 4-channel strain-gauge signal conditioners similar to the multiplexer but with separate bridge-excitation capability for each channel. For digitizing dynamic signals, you can capture data on all channels simulta-

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neously by triggering the multiplexer or the strain-gauge signal conditioners from a data strobe you supply; these modules are ready to accept new data at a 100-kHz rate. $1500 to $1900. Delivery, eight weeks ARO.

Hewlett-Packard Co, 1820 Embarcadero Rd, Palo Alto, CA 94303. Phone local office.

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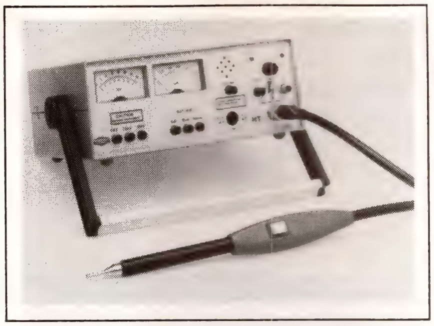
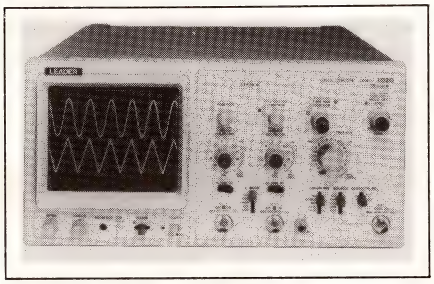




LOW-COST SCOPE

- *Maximum sensitivity is 0.5 mV/div*
- *Bandwidth is 20 MHz*

The dual-channel Model 1020 provides all of the oscilloscope functions required in many applications. The instrument has an 8×10-cm viewing area with an illuminated internal graticule, a 20-MHz bandwidth, and maximum sensitivity of 0.5 mV/div. Trigger capabilities include alternate-channel triggering, variable trigger holdoff, TV-sync separation, and line triggering. $595.

Leader Instruments Corp, 380 Oser Ave, Hauppauge, NY 11788. Phone (800) 645-5104; in NY, (516) 231-6900. TWX 510-227-9669.

Circle No 445

INSULATION TESTER

- *Portable unit weighs 9.5 lb*
- *Performs nondestructive testing to 15 kV*

Operating from 110/240V 50- to 400-Hz ac mains or a bolt-on 12V battery pack, the 9.5-lb Model JP15 nondestructive insulation tester provides output voltage adjustable from 0 to 15 kV. To safeguard operating personnel and the equipment under test, the tester limits discharge energy. You can monitor insulation leakage current on a front-panel-mounted meter that provides 10-nA resolution on its most sensitive range and reads 100 μA on its highest range. The unit also includes an ionization detector with an active lowpass filter and provides an audible output via an internal

loudspeaker or a headphone jack. $2185.

RE Instruments Corp, 31029 Center Ridge Rd, Westlake, OH 44145. Phone (216) 871-7617.

Circle No 446

DEVELOPMENT SYSTEM

- *Supports 80286, 68000, 68010, 68012, and 68020*
- *Allows memory updates while user program runs*

The vendor can configure the SA98 development system to support the 80286, 68000/10/12, or the 68020. Its zero-wait-state emulation allows memory and I/O modifications as well as high-speed data transfers to and from the target system while your program continues to run. The system provides a trace buffer 4k words deep and can use pods that the vendor supplied with earlier in-circuit emulators. The unit, which is compatible with Intel OMF, Tektronix Hex, and Motorola S records, uses a single I/O slot in a PC bus-based host for its parallel interface card. $7000 to $16,500.

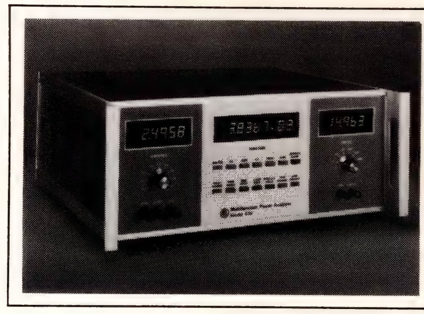
Sophia Computer Systems Inc, 3337 Kifer Rd, Santa Clara, CA 95051. Phone (408) 733-1571. TLX 853394

Circle No 447

POWER ANALYZER

- *3-channel display includes rms current and voltage*
- *Also measures seven other quantities*

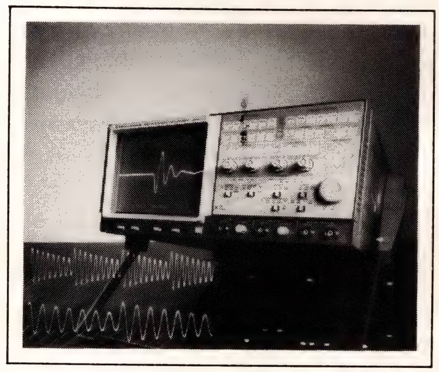
You can use the Model 636 multifunction power analyzer at 50 or 60 Hz. Its 3-channel, 5-digit LED display indicates ac voltage, ac cur-



rent, and one other parameter you can select from the front panel. For most measurements, accuracy is 0.05% of reading. Besides true-rms voltage and current, the variables measured include real, complex, and reactive "power" (watts, VA, and VARs), watt-hours, VAR-hours, power factor, and frequency. Measurement ranges extend from 4 to 660V, 25 mA to 55A, and 150 mW to 36 kW. An IEEE-488 interface is optional. $7500.

Dowty RFL Industries Inc, Powerville Rd, Boonton, NJ 07005. Phone (800) 242-7421; in NJ, (201) 334-3100.

Circle No 448



STORAGE SCOPE

- *Samples single-shot events at 100M samples/sec*
- *Features on-screen cursors for trace measurements*

The BOS 2-channel digital storage oscilloscope's 100-MHz sampling rate and 10224-word trace memory let you capture single-shot events that last longer than 102 μsec. For example, you can record and analyze a complete TV video line. Further, you can add, subtract, or multiply the two input channels together,

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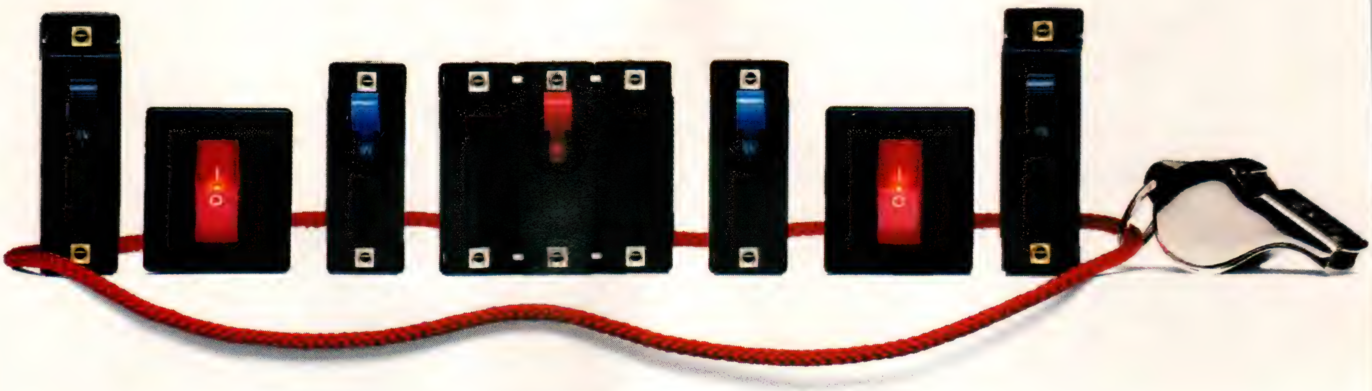

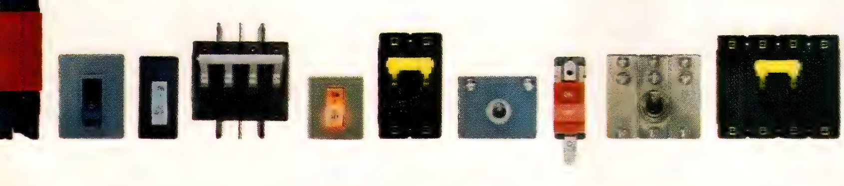

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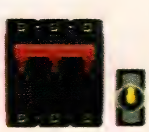

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CIRCLE NO 195

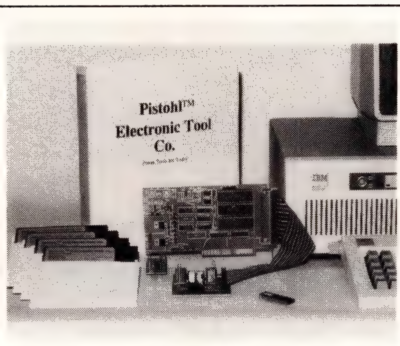
and integrate, differentiate, or square them. Besides displaying the traces, the oscilloscope's 7-in. CRT provides two measurement cursors and offers digital readout of the relevant oscilloscope settings. You can use the cursors to perform relative-voltage and time measurements between any two points on the trace, or absolute-voltage measurements and time-difference measurements from the oscilloscope's trigger point. The oscilloscope can display the traces in the dot, linear-interpolation, or sine-interpolation modes. The instrument comes with an IEEE-488 instrument-control interface; you can order it with an option that lets you store a sequence of 10 instrument setups max in the nonvolatile memory. You can download captured traces to an IEEE-488-compatible digital plotter or to an XY recorder. Around $5000.

Rohde & Schwarz GmbH, Muhldorfstrasse 15, 8000 Munich 80, West Germany. Phone (089) 41290. TLX 523703.

Circle No 449

Rohde & Schwarz, 4425 Nicole Dr, Lanham, MD 20706. TWX 510-223-0414.

Circle No 450



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- *Generate JEDEC fuse maps from Boolean equations*
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Pistohl Electronic Tool Co, 22560 Alcalde Rd, Cupertino, CA 95014. Phone (408) 255-2422.

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TLX-932	640 × 200	1/200	0.375 × 0.375	293 × 97.6 × 14	No	T7779
TLX-561	640 × 200	1/200	0.35 × 0.49	275 × 126 × 14	Yes	T7779
TLX-711A*	240 × 64	1/64	0.53 × 0.53	180 × 65 × 12	Yes	T6963C**
TLX-341AK*	128 × 128	1/64	0.45 × 0.45	93.2 × 86.6 × 12	No	T6963C

*Under development, **Built-in controller

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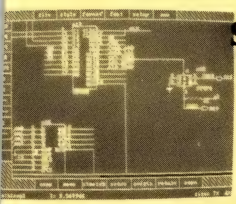

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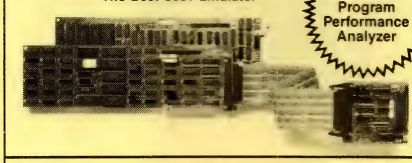

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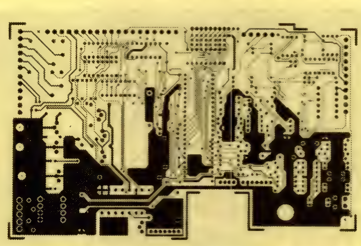

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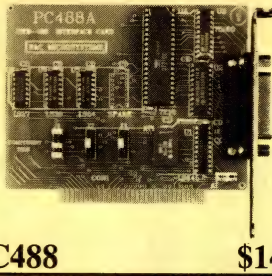

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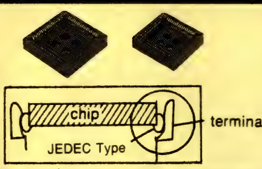

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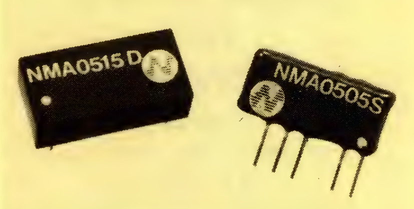

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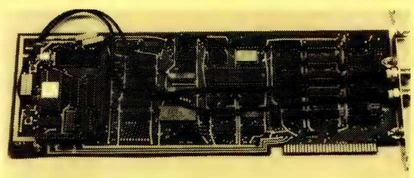

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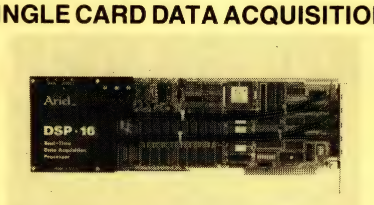

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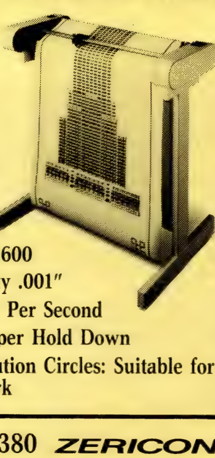

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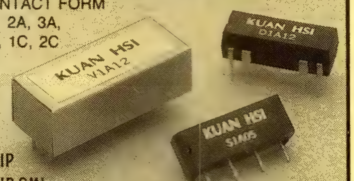

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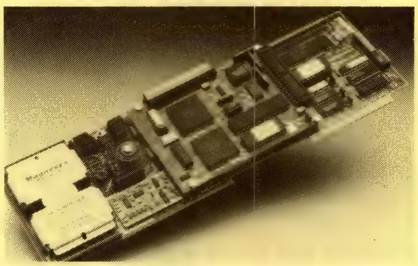

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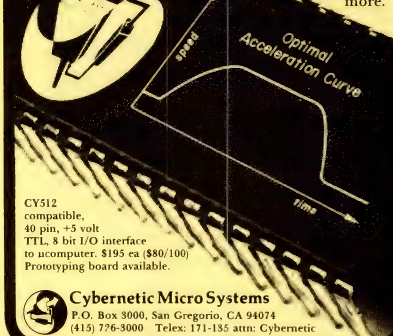

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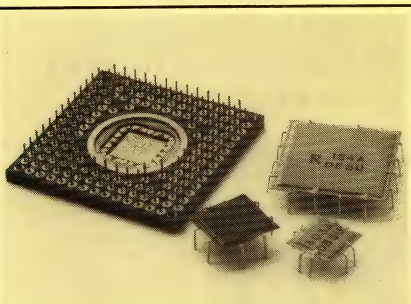

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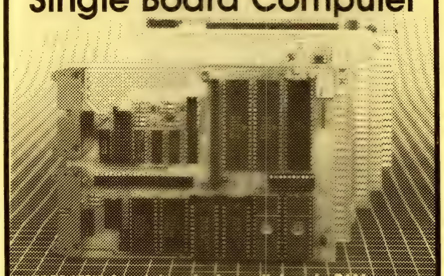

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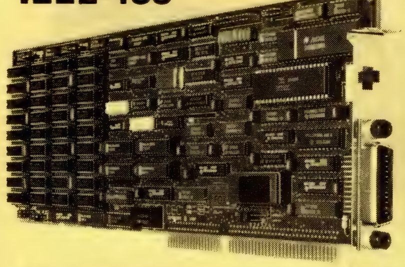

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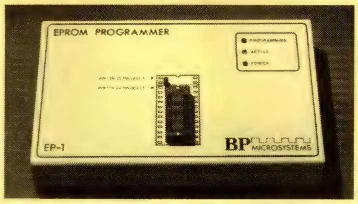

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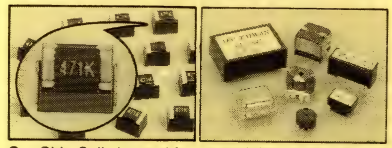

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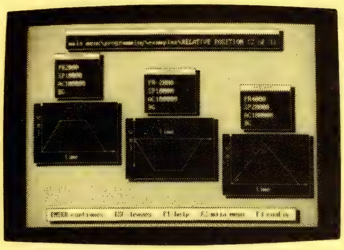

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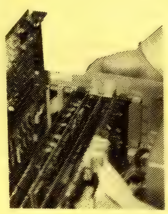

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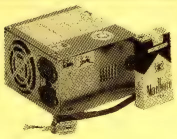

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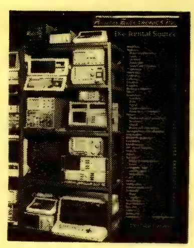

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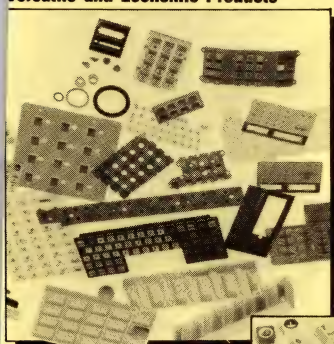

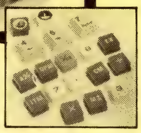

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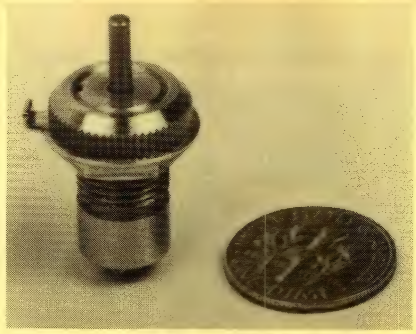

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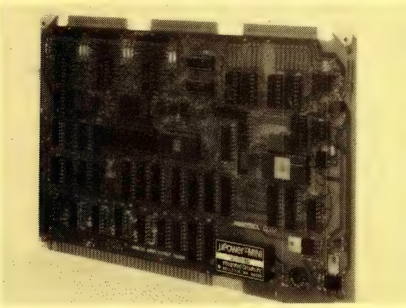

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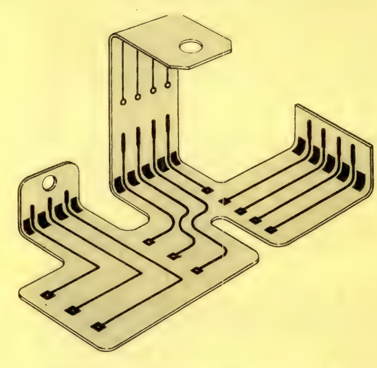

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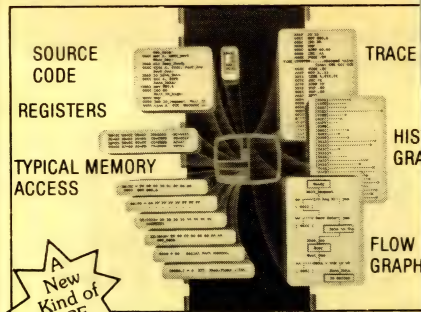

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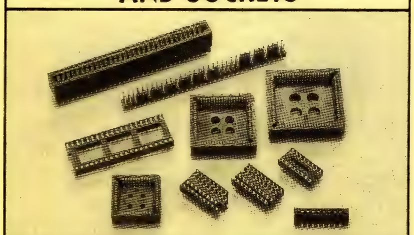

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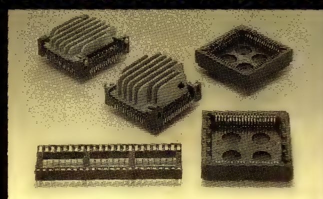

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(Please circle)	$780	750	730	660	640	630	620	595

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Address ____________________
City ____________ State ________ Zip ________
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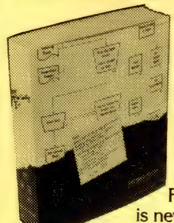
Mail to: EDN / 275 Washington Street / Newton, MA 02158-1630

EDN PRODUCT MART appears in every issue — 26x a year!

To advertise in Product Mart, call Joanne Dorian, 212/463-6415



Flow Charting II+
The New Plus for Fast Flowcharting

FLOW CHARTING is new! It's now Flow Charting II+, with more speed + more functions + more printing options;

• 10 text fonts; 26 shapes; • Line mode can stop at a shape; • Backspace key can erase a line to its origin; • Free text entry anywhere, or select auto-centering; • Vertical or horizontal printing; one chart or multiple charts.

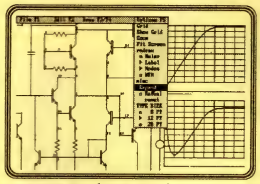
Used by Fairchild, Bechtel and more than 500 other major corporations. Edit quickly and accurately — even major edits — with Flow Charting II+, the Specialist.

See your retail store or call:

PATTON & PATTON
Software Corporation
800/672-3470, ext. 897 California
800/538-8157, ext. 897 National
408/629-5044 International)

CIRCLE NO 235

Analog Circuit Simulation



NEW
SPICE_NET
$295.00

Make SPICE input files from schematic drawings using pull down menus and a mouse to draw and connect parts. Use an **IBM** PC with any UC Berkeley compatible SPICE program.

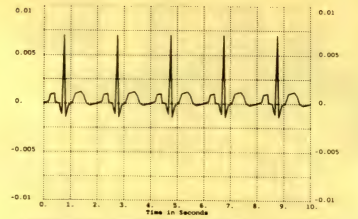
Simulation Programs for **IBM** PC's from ***intusoft***

- **IS_SPICE, $95.00.** Performs AC, DC and Transient analysis.
- **PRE_SPICE $200.00:** Adds Monte Carlo Analysis, Sweeps, Optimization, libraries and algebraic parameter evaluation .
- **Intu_Scope $250:** A graphics post processor works like a digital oscilloscope. Easy to use with all the waveform operations you will ever need.

(213) 833-0710

P.O. Box 6607
San Pedro, CA
90734-6607

CIRCLE NO 236



LOW COST ANALOG CIRCUIT ANALYSIS

Introducing a **NEW RELEASE** of **EC-Ace**, a subset of the powerful **ECA-2** analog circuit simulator. **EC-Ace** 2.31 includes all of the basics, with increased graphics, expanded documentation, and a new low price.

- AC, DC, Transient
- Temperature
- Interactive or batch
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- Over 100 nodes
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- Sine, Pulse, PWL, SFFM, and Exponential generators
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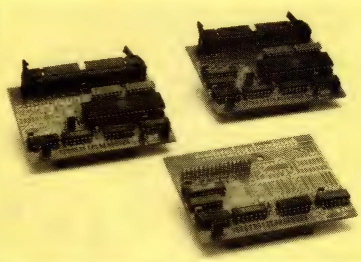
- Money back guarantee

EC-Ace 2.31 **$145**
ECA-2 2.31 IBM PC/XT/AT/PS-2 $675
An upgrade from **EC-Ace** to **ECA-2** is available.
Call 313-663-8810 For FREE DEMO disk

Tatum Labs, Inc
1478 Mark Twain Court, Ann Arbor, MI 48103

CIRCLE NO 237

SBX MODULES



We've upgraded our SBSxSCSI module to support Block-Mode Psuedo-DMA transfers. That means CPUs without DMA can increase transfer speeds by not polling for READY on every byte. We've also added an optional Centronics-compatible printer port (SBSxSCSI/CEN). If you only need the printer port, save money with our low-cost SBSxCEN module. We also offer a Floppy-Disk Controller module (SBSxFDC) that handles 3½″, 5¼″, and 8″ drives with SD, DD and HD formats.

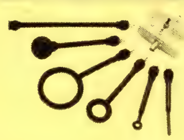
Call or write for more information.

Single Board Solutions, Inc.
20045 Stevens Creek Blvd.
Cupertino, CA 95014
(408) 253-0250

CIRCLE NO 238

E & H Field Probes

$495



EDN "Readers Choice" (6/25/87)

Makes finding E & H Field emissions easy!

Use with any o-scope or spectrum analyzer. Set includes three H and two E field probes, extension handle, case, documentation, two year warranty. Pre-amp with battery charger, optional. Call, write to order or for brochure.

1-800-253-3761
PO Box 1546 Austin, TX 78767

EMCO
The Electro-Mechanics Company

CIRCLE NO 239

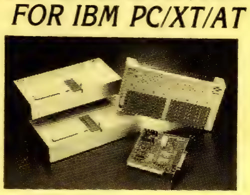
Want Attention From 137,000 Engineering Specifiers?

◆

Place your ad in EDN Product Mart.

CIRCLE NO 240

PROGRAMMERS
FOR IBM PC/XT/AT



- Select Device with vender name & type number directly
- Enable user to set up Program Pulse Width, Vpp, Vcc, Over-program Pulse Width & Iteration Counts.
- Capable of set & 8/16/32-bits wide-word programming.
- Built in Intellec Hex, Tektronix Hex, Motorola S, Hexadecimal, JEDEC transmission formats.
- Suspend to DOS for operation of DOS utilities.

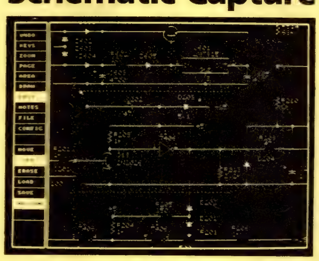
XP6000	Adapter & cable installs in PC for connecting program mer externally	**$ 55**
XP6001	1-socket 1M-bits EPROMs programmer	**$160**
XP6002	8-socket 1M-bits EPROMs programmer	**$375**
XP6003	1-socket MCS-48 micros programmer	**$215**
XP6004	1-socket MCS-51 micros programmer	**$270**

2 YEARS GUARANTY + 30 DAYS MONEY BACK WARRANTY

Xender
Xender Corporation
2824, KENNEDY BLVD., JERSEY CITY, NJ 07306
TEL: 201-659-2258 Tlx: 910 240 4444 CHAMPION

CIRCLE NO 241

SCHEMA II
Schematic Capture



FREE Demo Disk: 1-800-553-9119

SCHEMA's success is the talk of the CAE industry and *thousands* of satisfied SCHEMA owners know why. Incredible speed, ease of use, and power have made SCHEMA a best-selling schematic capture program for engineering professionals the world over.

Now, SCHEMA II is available. SCHEMA II sells for $495 and supports most common IBM PC/XT/AT configurations. Please call today for a *free* SCHEMA II demo disk.

OMATION
In Texas Call (214) 231-5167

CIRCLE NO 242

ZIPPY SWITCHES

UL NO: E91274

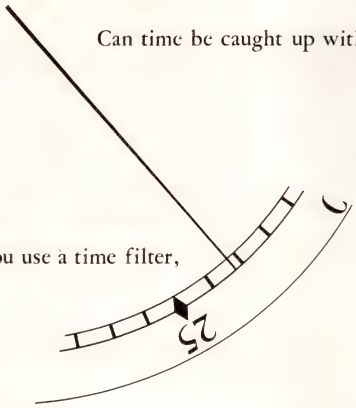
*FUll DETAILS AND SAMPLES ON REQUEST
*OEM ARE WELCOME

ZIPPY SHIN JIUH CORP.
P.O. Box 10184 SHIN TIEN TAIPEI HSIEN, TAIWAN, R.O.C.
TEL:(02) 9188512-5 TLX:33418 ZIPPY FAX:886-2-9155765

CIRCLE NO 243

To advertise in Product Mart, call Joanne Dorian, 212/463-6415

Can time be caught up with?



Yes, if you use a time filter,

the natural corner-stone in digital correlation - making high resolution and wide delay span easy.

Delay LS-16 is good for more than 100 Ms/s, and it creates a time domain of 16 384 points! It´s a new step in pulse stream pattern analysis.

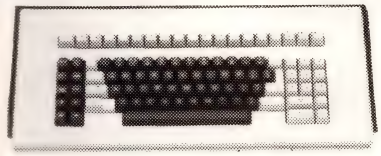
METRETIQ

Lilla Fiskaregatan 12
S-22222 Lund, Sweden

Telephone: 46 46 160915
Telex: 32837
Fax: 46 46 128792

CIRCLE NO 198

KEYBOARDS
STANDARDS



MODEL 8000
19" L x 8" W
Low Profile

● State-of-the- art microprocessor keyboard, 95 keys, including 19 special functions keys ● High reliability performance ● 4-wire serial interface, 300 or 1200 baud ● Unique variable key rollover with phantom key lockout ● High speed operation ● Ergonomic design.

CUSTOMS

GRI builds custom keyboards to your exact specifications and drawings for all types of applications - air traffic control, process control, military, etc. Our lighted keyboards are especially attractive due to their visibility and high reliability. We offer both dry reed and mechanical contact switch technologies.

QUALITY ● RELIABILITY ● SERVICE

GEORGE RISK INDUSTRIES, INC.
GRI Plaza
Kimball, Nebraska 69145
1-800-445-5218 - Sales
308-235-4645 - Technical

CIRCLE NO 199

Check rising costs

It's arrived – our new all purpose fuseholder system, series 19800.

Yet another innovative result of Wickmann technology. Fuseholders for 5 × 20 mm and 6,3 × 32 mm fuses feature extra solid contact pins, compatibility with existing shock-safe fuseholders, and sealed terminals.
Now everyone can afford superior circuit protection.

Hanover Fair
Open-Air Section,
Stand 26

A mark of safety

Wickmann-Werke GmbH
Annenstr. 113 · Postbox 2520 · D-5810 Witten 6
Tel. 02302/6620 · Telex 8229145wwg d · Fax 02302/662111

CIRCLE NO 200

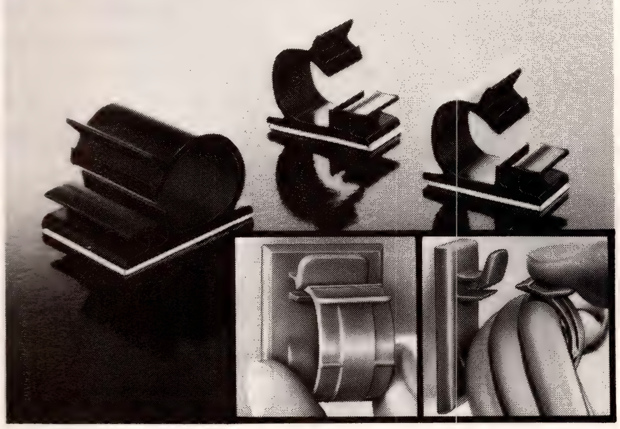
When wire runs where your tools won't reach...

Let us keep you in place

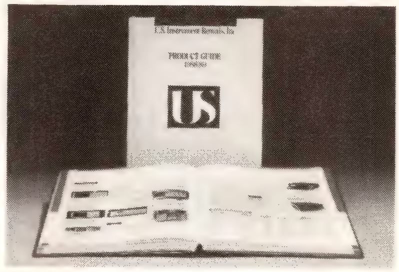
- Strong adhesive mounting system—keeps wire in place without screws or ties.
- Quick lock/release gives instant access to cable bundles.
- High impact material will not creep or deform.
- Choose from 8 sizes—3/16" to 1-1/2" wire bundle capacity.

the wire organizers *For more information write today*

dek, inc.
3480 Swenson Avenue
St. Charles, IL 60174
Phone: (312) 377-2575



CIRCLE NO 201



Guide to instrumentation

The vendor's 1988/1989 product guide informs you about more than 5000 different models from major manufacturers of electronic test and measurement instruments, data-processing equipment, and telecommunications test devices that you can rent, lease, or buy. The 400-pg reference book contains specifications, descriptions, photos, and other technical data. Included in its listings are analyzers, CAE/CAD equipment, generators, meters, recorders, oscilloscopes, signal modifiers, microcomputers, and general telecommunications test equipment.

US Instrument Rentals, 2988 Campus Dr, San Mateo, CA 94403.

Circle No 525

Handbook covers X/Open system

The *X/Open Portability Guide* sets forth the specifications of the Common Applications Environment (CAE) for compliant systems and software. The CAE comes from the commitment of an independent group of international computer-system vendors to worldwide development of a standards-based, open-systems philosophy based on the Unix system. $125.

X/Open Company Ltd, 1750 Montgomery St, San Francisco, CA 94111.

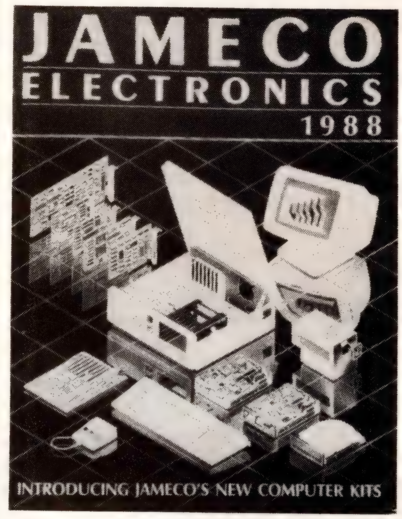
INQUIRE DIRECT

Instructions for using the 030

The user's manual for the MC68030, a member of the vendor's MC68000 software-compatible μP family, is now available. It describes the microprocessor's operating and programming capabilities. Information in some of its 14 sections covers data organization and addressing capabilities, processing states, the instruction set, and instruction-execution timing. The appendix summarizes the MC68000 family. $6 plus 15% shipping and handling.

Motorola Inc, Literature Distribution Center, Box 20924, Phoenix, AZ 85036.

INQUIRE DIRECT



Listing of computer/electronic products

The vendor's 1988 illustrated catalog lists more than 5000 items. The product lines feature a variety of items from computer kits and peripherals to integrated circuits. An 8-pg insert highlights IBM, Apple, Commodore, and Tandy computer peripherals. Also included is a 6-pg insert of pin-out data.

Jameco Electronics, 1355 Shoreway Rd, Belmont, CA 94002.

Circle No 526

Booklet documents board test methods

The 80-pg booklet *HP 3065 Board Test Family* covers three in-circuit and two combinational board test systems. Divided into six sections, it presents an overview of family products; family software; sections

VF Technology... The Bright Decision

Futaba, a world leading manufacturer of vacuum fluorescent displays, offers a wide assortment of *display tubes* in many sizes and formats. Also, Futaba offers *display modules* with all the electronics required to refresh the display and easily interface with the host system.

GRAPHIC DISPLAY

Both front glass phosphor, which provides maximum viewing angle and uniform surface appearance, and conventional back glass phosphor, with optimum brightness and software dimming capabilities, are available. All Futaba graphics modules offer complete drive electronics, bit mapped control with a DC/DC converter. All active components are surface mounted onto a single board.

DOT MATRIX MODULES

Utilizing Futaba's dot matrix displays, a completely intelligent line of "dot modules" is available. Each includes all drive, power supply and microprocessor components surface mounted onto a single board. Surface mounted technology results in higher reliability and allows for a smaller overall package and lower cost. All dot modules require only a 5V DC power source and can accept parallel or 8 possible serial baud rates.

GRAPHIC DISPLAYS/MODULES

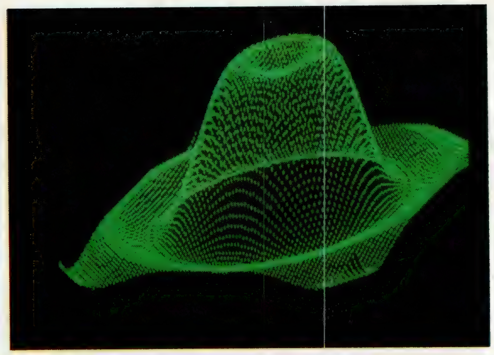
Futaba Display	Futaba Module	Pixels (Row X Char.)	Brightness (FT-L)	Module Dimensions (in.)
GP1005B	GP1005B03	128X64	400	7.28X3.35X1.77
GP1006B	GP1006B04	256X64	200	9.84X3.35X1.77
GP1009B	GP1009B03	240X64	200	6.2X2.76X1.57
GP1010B	GP1010B01	176X16	200	7.32X2.16X1.70
GP1002C	GP1002C02	320X240	100*	7.10X6.30X1.60
GP1004B	GP1004B03	640X400	30	9.65X7.28X1.85

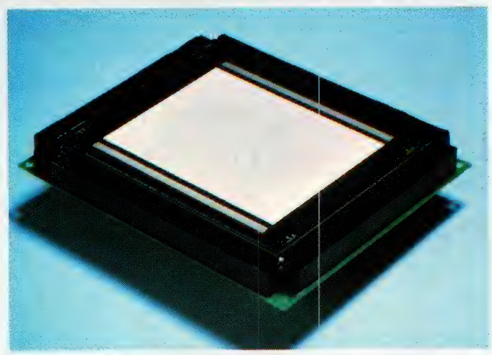
*Different Versions Available

DOT MATRIX DISPLAYS/MODULES

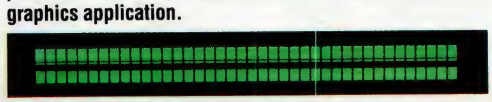
Futaba Display	Futaba Module	Char. X Row	Dot Format	Char. Ht. (in.)	Module Dimensions (in.)
20SD01Z	M20SD01	20X1	5X7	0.200	6.3X1.97X.75
20SD42Z	M20SD42	20X1	5X12	0.344	7.1X2.16X.88
40SD02Z	M40SD02	40X1	5X7	0.200	9.45X2.16X.88
40SD42Z	M40SD42	40X1	5X12	0.344	9.45X2.16X.88
202SD03Z	M202SD03	20X2	5X7	0.200	6.7X2.56X.90
402SD04Z	M402SD04	40X2	5X7	0.200	10.43X2.56X.90

MANY OTHER DISPLAYS **NEW MODULES AVAILABLE SOON**

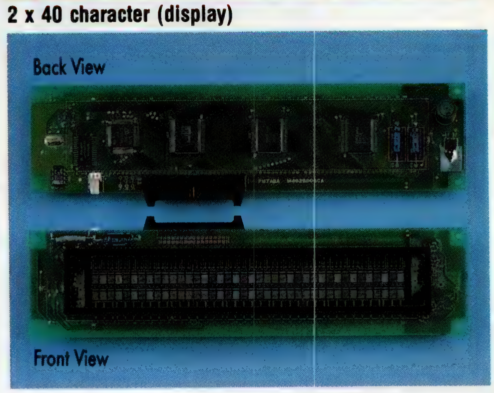




Compact, flat panel graphic displays and modules present clean, sharp images, whether for text or full graphics application.



2 x 40 character (display)



2 x 40 character (module)

Pattern flexibility and pleasing appearance are offered by Futaba in dot displays and modules.

Futaba also offers a complete catalog of alphanumeric, segmented displays.

Futaba supports its products with design engineering and system integration assistance. Call or write today.

FUTABA
Corporation of America
Electronic Components Division

711 E. State Parkway
Schaumburg, IL 60173

Telephone: (312) 884-1612
or (312) 884-1444

on analog, digital, and mixed-signal test methods and specifications; and general information. Within the text, special symbols indicate supplemental characteristics that provide information you can use in applying or appraising a system.

Hewlett-Packard, 1820 Embarcadero Rd, Palo Alto, CA 94303.

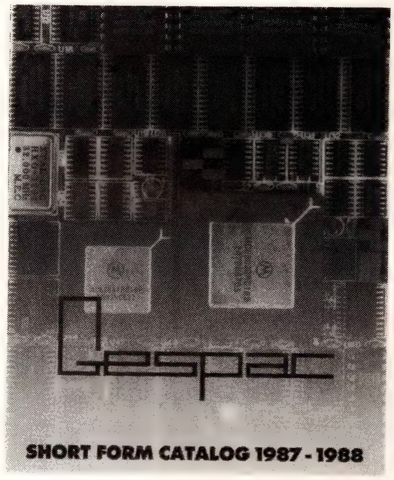
Circle No 527

Computer printers displayed

This fold-out brochure illustrates the vendor's full line of computer printers that are suitable for business, scientific, or personal applications. Besides listing the printing speeds, performance capabilities, and special features of each printer type, it presents the options, accessories, and supplies that are available.

Seikosha America Inc, 1111 MacArthur Blvd, Mahwah, NJ 07430.

Circle No 528



G-64 bus products categorized

The vendor's Short Form Catalog 1987-1988 covers more than 100 board-level products, as well as the complete line of systems and software tools, operating systems, and high-level languages. Special features and suggested applications for the G-64 bus complete the brochure.

Gespac Inc, 50 W Hoover Ave, Mesa, AZ 85202.

Circle No 529

Software system provides manufacturing solutions

Presenting Max, The Production Manager, a microcomputer-based software system for manufacturing control, this 6-pg brochure examines the system's features and advantages. A floppy disk entitled *AutoMax* explains the benefits and features of Max and the microcomputer MRP II, and is available to anyone interested in the vendor's products.

Micro-MRP Inc, Century Plaza I, 1st Floor, 1065 E Hillsdale Blvd, Foster City, CA 94404.

Circle No 530

EDN NEWS


Combining EDN Product News and EDN Career News

EDN NEWS

Memory Boom by Mid-1990

National Supplies Chips to Opus

Military Gate Arrays

Low-Cost Spectrum Analyzer

Reflectometer Isolates LAN Faults

EE Education Gets a Boost in New Jersey

A CAHNERS PUBLICATION

NEWSBRIEFS

Agreement

Display

MIL Standards

Custom Software

Design Center

Price Cuts

Venture Capital

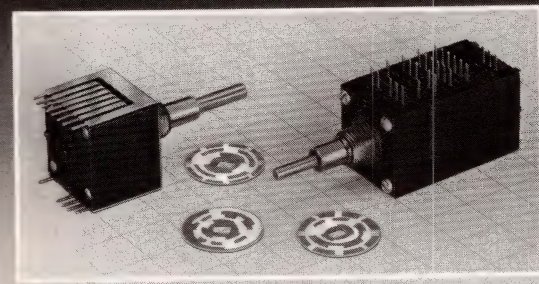
INSIDE

DSP Board Fits IBM PC

Power MOSFET Makers Boost Electrical Specs

HOT NEWS OF PRODUCTS, TECHNOLOGY, AND CAREERS

MM P/REL™
Encoded Rotary Switch



The leader in digital rotary switching now brings you:

- Just .865″ square
- Enclosed, wave solderable construction
- Fixed or adjustable stops available
- 50,000 cycles
- Programmable to customer truth table

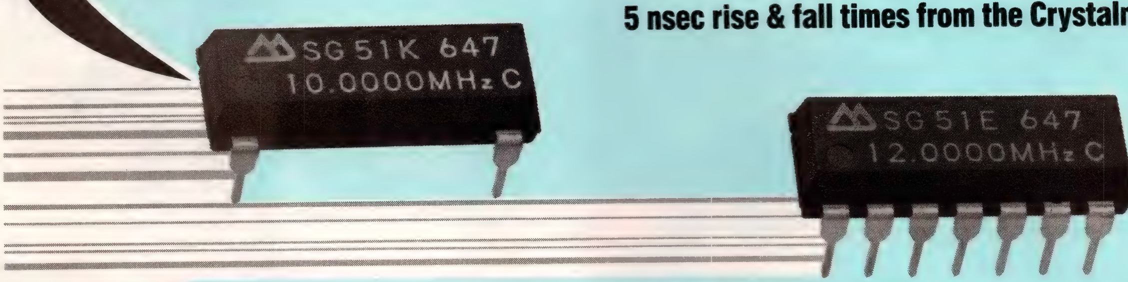
Call or write for applications assistance.

STANDARD GRIGSBY

920 Rathbone Avenue/P.O. Box 1528 • Aurora, Illinois 60507 USA
312 844-4300 • TWX 910 232-3138

CIRCLE NO 205

5 nsec rise & fall times from the Crystalmaster



HIGH SPEED, AUTO INSERTABLE, CMOS

PLASTIC DIP OSCILLATOR!

The new EPSON SG-51 Series plastic DIP CMOS crystal oscillator has typical 5 nsec rise and fall times. And it occupies about half the board space of the metal can oscillator it replaces. Both versions of the SG-51, 4-pin and 14-pin, are auto insertable using standard DIP equipment, and the 4-pin fits the same hole pattern as metal can types. With tri-state output, low power consumption, high speed and now 4-pin or 14-pin plastic DIP... the Crystalmaster is first again!

OUTPUT FREQUENCIES

20.0000 MHz	12.0000 MHz	6.1440 MHz	3.0720 MHz
19.6608 MHz	10.0000 MHz	6.0000 MHz	2.5000 MHz
18.4320 MHz	9.8304 MHz	5.0000 MHz	2.4576MHz
16.0000 MHz	9.2160 MHz	4.9152 MHz	
12.2880 MHz	8.0000 MHz	4.0000 MHz	

SPECIFICATIONS

CMOS Crystal Oscillator SG-51 Series

Input Voltage:	5V ± 0.5V
Access Time:	8 nsec MAX, 5 nsec TYP
Frequency Stability:	C = ±100 ppm
Duty:	40/60 to 60/40% at 1/2V_{DD} or 1.4V level
Current Consumption:	18mA MAX, 10 mA TYP at 12 MHz
Output Load:	10 TTL gates

Call us now for detailed information

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OEM Division
Component Sales Department
3415 Kashiwa St., Torrance, CA 90505

Telephone (213) 534-4500 • TELEX 664277 • FAX (213) 539-6423

CIRCLE NO 206

Best performance in a supporting role.

And the winner is . . . Carlingswitch. For any application.

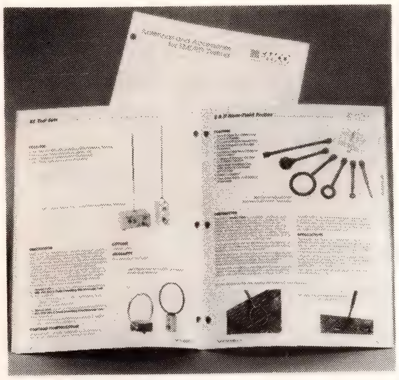
Our full line of innovative switches (full-size and miniature) and high-performance circuit breakers includes some of the biggest stars in the business: Curvette,® Curvette SC,™ Tippette,® VisiRocker,® Lockette™ and Rotette™. . . all internationally approvable.

And for behind-the-scenes technology and know-how, Carlingswitch wins again – with CAD/CAM engineering, computerized integrated manufacturing and Statistical Process Control to maintain rigid standards of quality. Plus, there's the special expertise that only comes with experience . . . and we've been supporting great ideas since 1920. Let Carlingswitch help make your next production a big hit.

For more information on our full line of top performers, call toll free: 1-800-243-8160. Or write: Carlingswitch, Inc., 60 Johnson Avenue, Plainville, CT 06062-1165. (203) 793-9281. TELEX: 710-425-0034. FAX: (203) 793-9231.

CARLINGSWITCH
INNOVATION BY DESIGN

CIRCLE NO 207



Antennas and accessories

The vendor's 1988 catalog of antennas and accessories for EMI/RFI testing and a 20×30-in. 1988 calendar with a product- and antenna-selection guide on the back are available. In addition to product information, the catalog features FCC and VDE regulations, tables that help you make a selection, and a list of formulas.

EMCO, Box 1546, Austin, TX 78767.

Circle No 531

App note helps you calibrate DP transmitters

Application Bulletin P-80 tells you how to calibrate differential-pressure (DP) transmitters on site, thus eliminating the task of having to remove the DP cells and take them back to the shop for calibration. It also describes three calibration devices and provides illustrations.

Rochester Instrument Systems Inc, Test & Calibration Products, 255 N Union St, Rochester, NY 14605.

Circle No 532

Guide for selecting printer/plotter

The 8-pg brochure *Selecting the right narrow format printer/plotter for your hard copy needs* helps you choose a narrow-format electrostatic or a thermal-transfer printer or plotter, and it describes both monochrome and color devices. The publication considers the advantages of electrostatic and thermal-transfer plotting for producing narrow-format hard copy. Also included is information about the V-80, Spectrum, and Versacolor plotters. A product table compares the specifications of the three plotters.

Versatec, 2710 Walsh Ave, Santa Clara, CA 95051.

Circle No 533

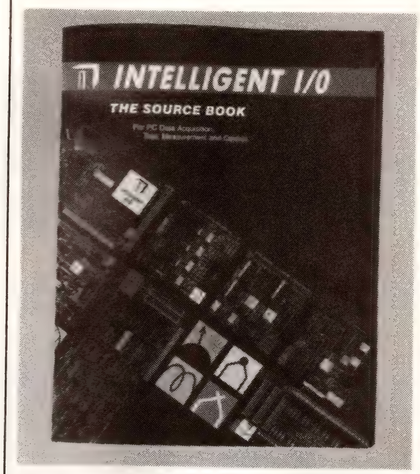
Guide to multiuser system

The *Multiuser Reference Guide* helps you turn an IBM PC/XT, PC/AT, or a compatible computer into a host/file server for a multiuser system. The publication explains different DOS-compatible, multiuser technologies, such as time-slicing, multiprocessing, and LAN-based solutions. Another section

tells you how to convert a personal computer into a multiuser system to use with non-DOS operating systems, such as Xenix, Concurrent DOS, or Pick.

Kimtron Corp, 1709 Junction Ct, Bldg #380, San Jose, CA 95112.

Circle No 534



Brochure covers data-acquisition systems

The Source Book, a combination catalog/handbook assists you in configuring customized personal-computer data-acquisition systems. It features carrier boards, instrument modules, termination panels, accessories, and the vendor's software, as well as software from other companies for data-acquisition systems. It also details IQ Paks, the vendor's PC data-acquisition start-up systems. Ordering information, conditions of sale, and an indexed price list complete the publication.

Intelligent I/O, 1141 W Grant Rd, #131, Tucson, AZ 85705.

Circle No 535

System components and reference data categorized

This 80-pg, pocket-sized catalog lists versions of the PC bus, Multibus, VME Bus, and Q Bus, as well as computers that are 100% compatible with IBM PCs. It provides descriptions and specifications for each product. Further, the application-information and reference-data sections contain useful features, such as application maps.

Diversified Technology, Box 748, Ridgeland, MS 39158.

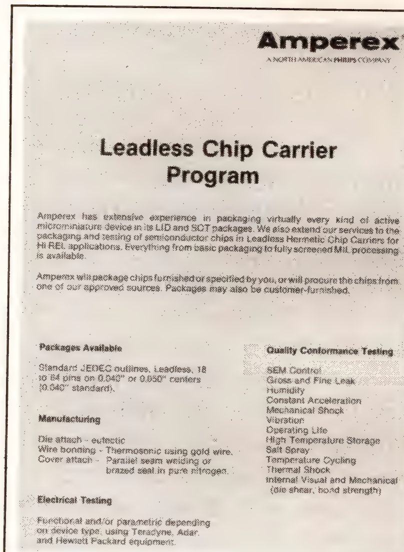
Circle No 536

Publication presents simulator

The 20-pg data sheet describes the L200 programmable dynamic-angle synchro/resolver simulator. It discusses simulation in detail, as well as the use of built-in instruments, programming, and applications. Specifications, and numerous illustrations and diagrams complete the pamphlet.

Natel Engineering Co Inc, 4550 Runway St, Simi Valley, CA 93063.

Circle No 537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Folder outlines LCC program

This 4-pg pamphlet outlines the vendor's leadless chip-carrier program. It lists the packages available, manufacturing methods, and types of electrical and quality-conformance testing. In addition to the manufacturing flow chart, it provides dimensional drawings for center-line chip carriers and explains the distinguishing features of the LCC types.

Amperex Electronic Corp, Providence Pike, Slatersville, RI 02876.

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Coaching turns engineers into public-speaking pros

Deborah Asbrand, *Associate Editor*

Bruce Richman is used to speaking before groups. Part of his job as section manager for Gould Semiconductor (Pocatello, ID) is to present monthly status reports to the division's upper management. After eight years of making the presentations, he rarely feels nervous. So when his employer asked him to attend a two-day class on public speaking, Richman thought he'd breeze through the class. He was wrong.

Among the classroom exercises was making a short videotaped presentation. That was the easy part. The hard part, he says, was watching the presentation played back. "I was very stiff; I looked like a stick," Richman sighs. "I wasn't Burt Reynolds."

Although engineering has the reputation of being well suited to individuals who prefer solitude, the demands of many engineering jobs are just the opposite. Not only do engineers need to communicate their ideas to other engineers, but they're also often required to explain projects to upper managers and sales representatives. In addition, many companies like to bring engineers along on sales calls, where they need to speak persuasively, as well as clearly, to potential customers. Many employers encourage engineers to keep a high industry profile by publishing articles in technical magazines and attending conferences.

Yet public-speaking opportunities can strike fear into the hearts of the most talented and confident people. "Fear of public speaking comes right before fear of death," says Carla Echols of Echols and Pryor, the San Francisco, CA, consulting firm that coached Richman and six other Gould engineers. And even people who are comfortable in speaking before a group can use pointers on organization and presence. To help engineers conquer their anxieties, more companies are enrolling them in classes that soothe nerves, polish delivery, and add panache

"Fear of public speaking comes right before fear of death."

Tim Davis

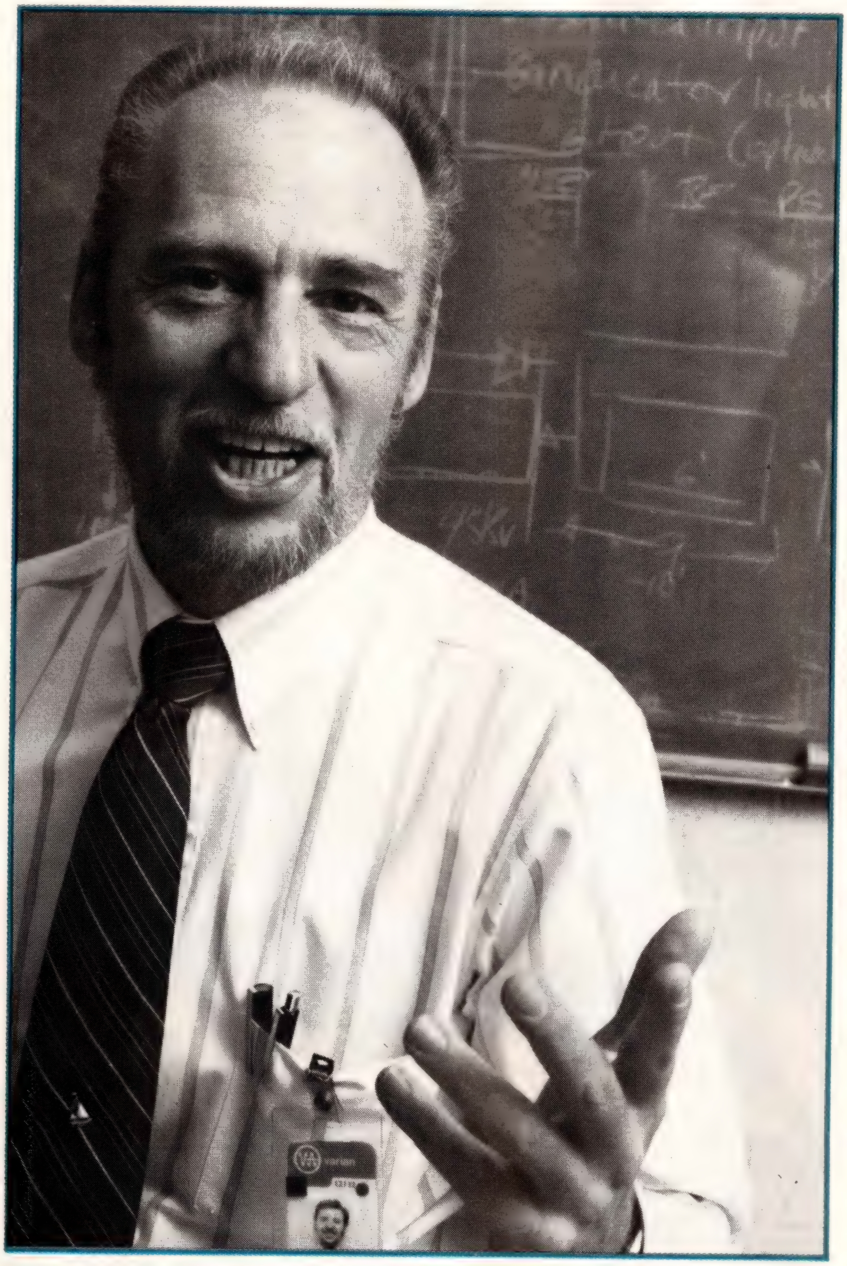
Carla Echols, Echols & Pryor

More companies are enrolling engineers in classes that soothe nerves, polish delivery, and add panache to a person's speaking style.

to a person's speaking style. Perhaps even more important, engineers report that becoming convincing speakers can help their careers.

Echols identified specific problems with the typical engineering presentation and gave Richman and his colleagues pointers on how to avoid them. For example, the hallmark of any technical presentation is detail, but including too many particulars can mean sudden death for a speech. "As speakers, engineers get lost in the detail," says Echols, and instead of explaining to the audience the major themes of their work, engineers often drown their viewers in slides, transparencies, and handouts. An equally common breed of speaker is the back-turner—the person who turns away from listeners and proceeds to read information on the viewing screen. "That's deadly," says Echols. "There's no need to read slides. The audience is perfectly capable of reading them." Furthermore, she adds, unreadable slides aren't worth including and usually signal a poorly prepared discussion.

Many untrained speakers forget their audience's needs. But keeping listeners in mind helps a speech in two ways. First, when a talk is put together with its audience in mind, the audience is more likely to grasp major points. Second, it relieves some of the pressure the speaker feels. "It's scary looking out at the audience and realizing you're the only one talking," says Echols. A speaker who considers the audience part of the presentation, however, often feels like part of a group effort rather than like a solo performer.



Tim Davis

Saul Gold, Varian Associates

Playing to the house

Learning how to play to an audience, however, is easier said than done. An important step in achieving this ability comes from understanding how others perceive you, and the key tool most speech instructors rely on is the video camera. Watching a tape of yourself giving even a 2-minute talk can be unnerving. It's also eye-opening. Idiosyncracies that go unnoticed during casual conversation become glaring distractions before a group of people. Some people are in the habit of tapping one foot as they speak; others cram their shirt pockets full of pens and pencils, distracting the audience from their material.

Watching their recorded performances with the sound turned off, speech-class students see their flaws only too clearly. Richman, for example, had deliberately adopted a formal, serious mien when he spoke, believing such a persona would make him a more credible speaker. But when he viewed himself on tape, he discovered that he came

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across as wooden, rather than reliable. "I was too strait-laced, too formal," he says. In class he practiced incorporating his natural affability into his planned speech.

Indeed, students in speech classes rehearse not only relaxing but also hand gestures and smiling, as well as making smooth use of a pointer, slide projector, flip chart, or microphone. "Part of the art of speech preparation is the choreography," says Susan Almazol, a senior partner with Communications Training Consultants in Sunnyvale, CA.

Among the most difficult—and important—moves for people to master is eye contact. "You might make contact with 75% of the members of the audience, but you really need to cover 100% so that no members of the audience feel left out," says Saul Gold, who is manager of equipment engineering for Varian Associates Microwave Tube Div (Palo Alto, CA) and a graduate of one of Almazol's classes.

In addition to coordinating physical choreography, speakers need to limber up their vocal cords to prevent the strained voice that indicates a nervous speaker. Students in Echols' classes, for example, repeat the words "king kong" several times. They also practice yawning loudly, relaxing their neck and facial muscles, and taking deep breaths. More troubling to the average person than the sound of his own voice, however, is the moment when he stops hearing that voice. "People are afraid of silence," says Almazol, "so they fill it with 'ums' and 'ahs.' Those silences usually last just a split second, but feel like an eternity."

Balancing form and function

Captivating speechmakers put as much effort into organizing the contents of their presentation as they do into its delivery. Speakers who make their points clearly keep their listeners tuned into their speech and don't allow their audience's attention to drift.

Preparation benefits speakers—and audiences—in another way, too: It can reduce a speaker's dependence on visual aids. Any conference-goer knows that sinking feeling of watching an orator walk up the steps of the podium armed with cartons of materials to be shown on the screen. "If you walk in with a box of 250 slides and a projector, you just lost half of your audience," says Tim Franey, manufacturing-engineering manager for GTE's Government Systems Corp in Mountain View, CA. Franey estimates he's attended a dozen conferences in his 22 years in engineering.

Though it's often unspoken, engineers' greatest fear about public speaking is that they'll be asked a question to which they don't know the answer. Despite many years of experience in talking in front of groups, Franey still dreaded being asked the unexpected question. An alumni of Almazol's class, he says that organizing the content of his technical presentations left him time to spend on anticipating audience queries. Franey also learned techniques to handle "that fellow in the audience who delights in harassing speakers. I say 'I'm glad you asked that question;' then I turn off the projector and spend a few moments discussing the point with the audience." By turning off the equipment, Franey says, he retains control over the session.

Richman employs a different approach. Speakers don't have to be know-it-alls, he says. "It's okay to say you don't know the answer to a question."

The reason that Gould Semiconductor hired a consultant to work with Richman and the other engineers was to refine the presentations they were scheduled to give at the 1987 IEEE Custom Integrated Circuits Conference. "So often when you go to conferences, if it's after lunch and the room is dark and there are slides on the screen, you see people in the last 10 rows snoozing," says company spokesperson Noelle Greene. Not wanting that fate to befall Gould's contingent of orators, the company put the engineers through two days of coaching.

Among those put through their paces was section manager John Wright. Though his coworker and classmate Richman felt comfortable with the idea of speaking before a large group, for Wright, the prospect "created a fair amount of butterflies." Under Echols' tutelage, Wright discovered that he had

Engineers' greatest fear is that they'll be asked a question to which they don't know the answer.

"A lot of decisions are made based on a presentation."

the habit—common to inexperienced speakers—of moving too quickly through his material: He finished a 20-minute exercise in her class in 10 minutes. To polish his presentations, he brushed up on eye-contact skills and practiced controlling a slide projector while holding a microphone.

His time slot at the conference—just before lunch on the program's third day—was far from ideal. The schedule gave him two long days to attend other presentations and ponder what his fate would be. "I didn't sleep very well the night before," he admits. Yet when he took the stage before the session's 200 attendees, armed with his notes and 30 slides, he felt relaxed and prepared.

Engineers who make regular presentations say that speech training also helps them to better convey their design needs to management. "A lot of decisions are made based on a presentation," says Richman. "How you present information and the confidence you show as you ask the company president for another $100,000 for equipment is going to help you a lot."

Such self-assurance can also help their careers. "It can be a real boost to getting your name known," says Gold. "When you sit in the background, it's a lot harder for people to become aware of your importance." Gold says that his willingness to speak before groups has opened opportunities to represent his division at corporate gatherings and gain a higher profile at the company.

The benefits of speech training apply equally to those with Gold's natural aptitude for public speaking and those who cringe at the thought of facing an audience. "You can't learn to be a brilliant speaker," says Echols, "but you can learn to be a well-organized, confident speaker whom the audience will respect for your technical expertise." **EDN**

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May 26	May 5	CAE, Software, Sensors/Transducers	Mailing: May 19
June 9	May 19	CAE, Analog ICs, Test & Measurement	Closing: May 29
June 23	June 2	Data Communications, DSP, Components	Mailing: June 16
July 7	June 14	Product Showcase—Vol. I, Power Sources, Software	Closing: June 23
July 21	June 30	Product Showcase—Vol. II, CAE, Test & Measurement	Mailing: July 14
Aug. 4	July 14	Sensors & Transducers, Analog ICs, Graphics	Closing: July 21
Aug. 18	July 28	Military Electronics Special Issue, Displays, Military ICs	Mailing: Aug. 11
Sept. 1	Aug. 11	Instruments, Op Amps, Computers & Peripherals	
Sept. 15	Aug. 25	Data Acquisition, Data Communications, Digital ICs	Closing: Sept. 1
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Nov. 24	Nov. 3	Microprocessor Technology Directory Graphics, CAE	Mailing: Nov. 17
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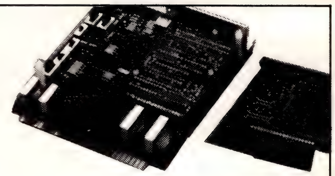

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Test Manager

You will be responsible for planning, organizing and directing DC and AC testing of CCD wafers and/or packaged devices. Supervising personnel in manufacturing and engineering test area will also be part of your duties, along with managing the test data base, participating in the testing activities and analyzing results. Qualified individuals must have a BSEE/Physics, or equivalent, plus 7 years experience including demonstrated ability to direct a team effort.

Test Engineers

As you play an active role in process control, you will also support DC and AC testing of CCD wafers and/or packaged devices, maintain test data base, and perform extensive analysis. This is a senior position requiring a BSEE, or equivalent, plus 2-4 years automatic test equipment experience. A solid knowledge of electronic circuit theory and physics is a must. Background in semiconductor processing would be helpful.

Reliability Engineers

Support reliability testing and analysis of CCD devices plus direct appropriate tasks for test technicians. You will provide feedback to Fab regarding device performance and support burn-in operation of packaged devices. Qualified individuals must have a BSEE/Physics plus 5-7 years experience in GaAs semiconductor reliability engineering.

Process Engineers

Be responsible for processing engineering in CCD wafer fab covering ion implantation, anneal, and CVD processes. You will set up and analyze process controls in fab and participate in statistical process control methods. We require a BSEE/Physics plus 2-4 years experience with knowledge of ion implantation, rapid thermal processing and plasma CVD processes.

Assume responsibility for process engineering in metallization, CVD and etch. You will direct tasks for fab process technicians and define, plan and execute process development projects. We require BSEE/Physics plus 2-4 years experience with knowledge of thin film deposition and etch equipment, including metallization lift off, alloy, chemical vapor deposition and dry etch processes.

Product Assurance Engineers

Prepare and document audits, inspection procedures and QA flow charts of CCD semiconductor processes/packaging. Perform product assurance duties such as materials review board member, failure analysis, audits and design reviews. We require a BSEE or equivalent plus 2-4 years experience in a semiconductor manufacturing environment. Packaging experience a plus.

Varian offers an excellent salary and benefits package which includes cash profit sharing and a 401(k) retirement savings plan. For immediate consideration, forward your resume including salary history, to Becky Fullerton, Varian Solid State Operations-California, 3251 Olcott St., Santa Clara, CA 95054. We are an equal opportunity employer.

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Professional Profile

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Home Phone (include area code): ______ Business Phone if O.K. to use: ______

EDUCATION

Degrees (List)	Major Field	GPA	Year Degree Earned	College or University

POSITION DESIRED ______

EXPERIENCE Present or Most Recent Position From: To: Title:
Duties and Accomplishments: Industry of Current Employer:

Reason for Change:

PREVIOUS POSITION:

Job Title: ______
Employer: ______ From: ______ To: ______ City: ______ State: ______
Division: ______ Type of Industry: ______ Salary: ______
Duties and Accomplishments: ______

COMPENSATION/PERSONAL INFORMATION

Years Experience	Base Salary	Commission	Bonus	Total Compensation

I Will Travel: ☐ Light ☐ Moderate ☐ Heavy — Date Available

Asking Compensation | Min. Compensation

☐ I own my home. How long? ______ I rent my home/apt. ☐

☐ Employed ☐ Self-Employed ☐ Unemployed

☐ Married ☐ Single | Height ______ Weight ______

Level of Security Clearance | ☐ U.S. Citizen | ☐ Non-U.S. Citizen

My identity may be released to: ☐ Any employer
☐ All but present employer

☐ WILL RELOCATE ☐ WILL NOT RELOCATE ☐ OTHER ______

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EDITED BY CYNTHIA B RETTIG

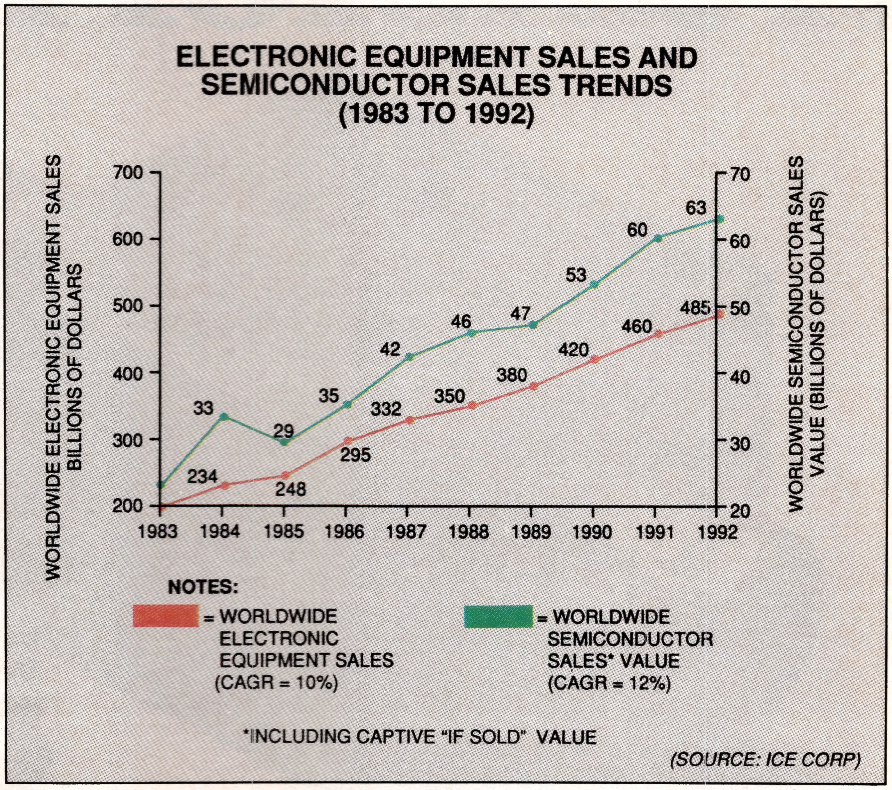
IC sales should achieve 12% CAGR from 1983 to 1992

According to Integrated Circuit Engineering Corp (Scottsdale, AZ), worldwide sales of integrated circuits should enjoy a 12% compound average growth rate (CAGR) from 1983 through 1992. Worldwide sales of electronic systems in general should experience a 10% CAGR in the same period. The higher growth rate for ICs reflects the steadily increasing use of semiconductors in electronic systems and underscores the connection between a healthy semiconductor industry and the production totals of electronic systems.

In order to avoid double counting and overestimating in its forecast, ICE subtracted the electronic-component figures from the overall production totals, published by various associations, that it used in compiling its study. These components include relays, antennas, disks, all active devices (ICs and discrete circuits), and capacitors and similar devices. In order to remove increases, or decreases, in in-house systems component inventories from aggregate forecasts, ICE also extracted component sales from systems figures.

Although the trend is toward increased production in Asian countries to the ultimate detriment of American sales, the US still leads in the production of electronic equipment and currently claims 43% of all sales. Moreover, it's crucial to remember that the recent decline in the US share of worldwide electronic equipment sales, when represented in dollars, results largely from exchange-rate fluctuations.

In 1987, worldwide sales of semiconductors, including ICs and discrete devices, were 23% higher than in the previous year, with IC sales growing by 27% and discrete-device sales by 9%. Although 1989 sales will only be 1% greater than those for the preceding year, sales will rebound nicely in 1990, 1991, and 1992, when growth is expected to equal 14%, 13%, and 12%, respectively. These estimates are based on 1987 constant dollars.



WORLDWIDE MERCHANT SEMICONDUCTOR SALES FORECAST
(MILLIONS OF DOLLARS)

YEAR	IC MERCHANT	% GROWTH OVER PREVIOUS YEAR	DISCRETE MERCHANT	% GROWTH OVER PREVIOUS YEAR	TOTAL MERCHANT SEMI	% GROWTH OVER PREVIOUS YEAR
1987	29,980	27	7,480	9	36,460	+23
1988	32,200	11	7,850	5	40,050	+10
1989	32,200	FLAT	8,150	4	40,350	+1
1990	37,200	16	8,650	6	45,850	+14
1991	42,400	14	9,350	8	51,750	+13
1992	48,000	13	10,000	7	58,000	+12

(SOURCE: ICE CORP)

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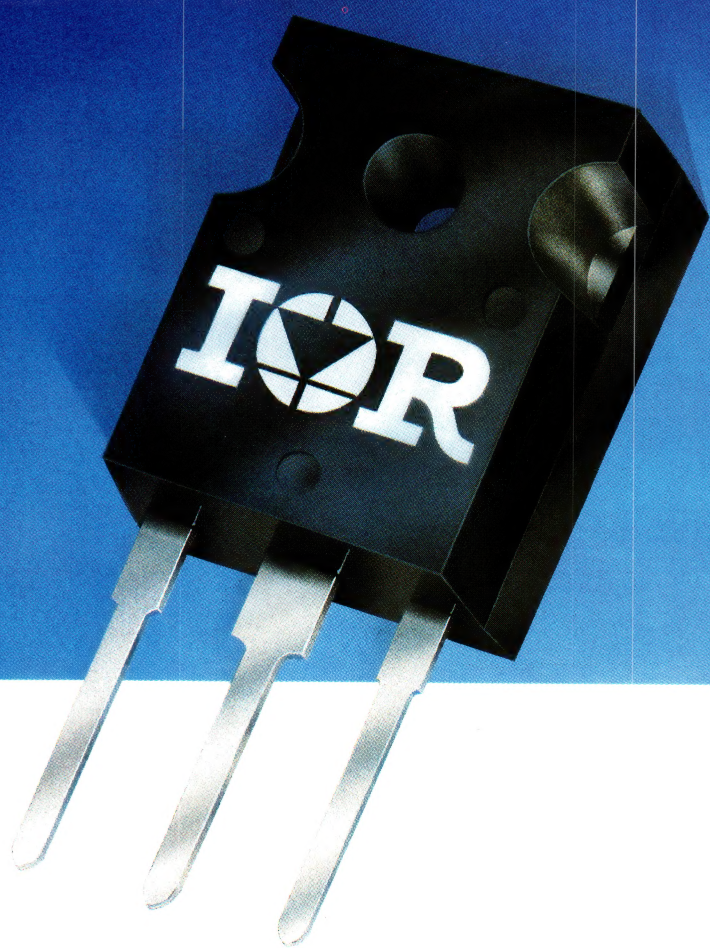

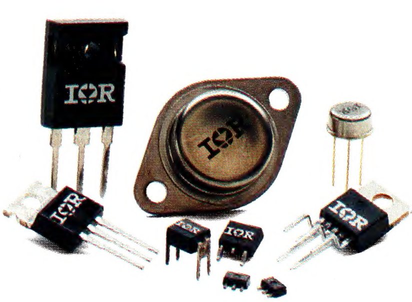

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